United States
Department of
Agriculture

Agricultural
Research
Service

37th Annual Conference Report on Cotton-Insect Research and Control

January 9-10, 1984
Atlanta, Georgia

RESEARCH--THE BASIS OF PROGRESS

Cotton-insect research reduces losses in cotton caused by insects and other arthropods and reduces the cost of managing insects. A continuing research program is essential if a favorable position is to be maintained in the battle with cotton pests. The ability of pests to develop resistance to highly effective insecticides emphasizes the need for a program of basic and applied research to develop strategies for managing pesticide resistance. New concepts and methods of control can come only through research.

Basic or fundamental research on the bionomics, physiology, biochemistry, and behavior of insects; on the chemistry of insecticides; and on the physiology of the cotton plant is essential to the development of new concepts of cotton-insect control. This research is essential before major breakthroughs can be achieved in developing insect-resistant cotton varieties, selective insecticides, and new concepts of control; in discovering effective attractants; and in making maximum use of biological control.

COOPERATIVE EXTENSION--PROGRESS THROUGH EDUCATION

The Cooperative Extension Service in each State bridges the gap between the researcher and the grower by making the most recent research results available for practical use at the farm level. The goal of Cooperative Extension Service entomologists, as well as of research entomologists, is to make cotton production more efficient by optimizing inputs and increasing profits through better and more economical insect control. Cotton-insect research is of value only when its findings are used by cotton growers.

AGRICULTURAL CONSULTANTS--IMPLEMENTATION OF PROGRESS THROUGH SERVICE

The many factors involved in integrated pest management are implemented at the field level. Proper decision making for managing cotton-insect pests is dependent on high levels of technical knowledge. Professional, qualified, licensed consultants provide expertise in developing necessary field information through a systematic monitoring program. The information is used in applying the most appropriate combination of practices based on research and extension recommendations for each field of cotton.

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Sponsored by
Agricultural Experiment Stations and Cooperative Extension Services of Alabama, Arizona, Arkansas, California, Florida, Georgia, Louisiana, Mississippi, Missouri, New Mexico, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia and the Agricultural Research Service and Animal and Plant Health Inspection Service of the U.S. Department of Agriculture and the National Cotton Council of America

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PREFACE

This Conference Report is available to anyone interested in cotton production. It may be duplicated in whole or in part, but it should not be used for advertising purposes. No less than a complete section relating to one material or insect, together with any supplemental statements, should be copied.

In utilizing the information presented in this report, individuals should recognize their responsibility with regard to the impact of pesticides on man and on his environment. Wherever possible, control measures consistent with good cotton-insect control and protection of the environment should be used. Insecticidal control techniques should be integrated with other suppression measures.

Most of the reports of the committees and study groups that were appointed to review and evaluate the status of persistent pesticides recommended that provisions be made for an orderly reduction in the use of persistent pesticides. In response to these recommendations, certain registered-use patterns have been canceled. These cancellations mean that farmers and other users often must exercise greater care and caution when protecting their crops with substitute insecticides. Certain of these substitutes such as organophosphorus insecticides may be more hazardous to humans than the previously registered pesticides because of their much higher acute toxicity. Pesticide registrations and recommendations are under constant review and are subject to change as warranted. It is the responsibility of all who recommend and use pesticides to be aware of the current status of pesticides and to be guided by it in recommending or using pesticides.

All pesticides are regulated by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as amended October 21, 1972, November 28, 1975, and September 30, 1978. The reader is encouraged to contact the nearest regional office of the Environmental Protection Agency for information and details on the provisions and regulations of FIFRA as amended.

CONFERENCE HIGHLIGHTS

Research

A test of the Z,Z-isomer of gossyplure or gossyplure at a rate of 4 or 1 g AI/acre, respectively, in 8 ha fields indicated 99.9% reduction in trap catches and elimination of mating of laboratory-reared pink bollworms in mini-mating stations. These results agree with those from earlier field plot tests and show that disruption of communication can be achieved by alteration of the ambient rates of component isomers of gossyplure, a new mode of action for control of pink bollworms by pheromone. (AZ)

Spray and point source methods of applying microencapsulated gossyplure or its Z,Z-isomer were compared for disruption of communication in pink bollworms. The spray method required more pheromone, probably due to different modes of action of sprays and point sources. Sprays must raise the levels of ambient pheromone to camouflage trails leading to females. Point sources act as baits to induce false trail following and, therefore, do not require high ambient pheromone to be effective. The results suggest that sprayable microencapsulated formulations may require higher rates of active ingredient to be effective. (AZ)

A 1-mg sample of microencapsulated gossyplure, placed on filter paper and used as a bait in live funnel traps, showed attractancy for a much longer period than a standard bait (1 mg in rubber septum). The microencapsulated baits were as attractive for 6 months in the field as rubber septa changed every 21 days. The original microencapsulated baits were removed from the field in early November, refrigerated, and then placed back in the field in August of the following year. These baits were still as attractive as rubber septum baits changed every 3 weeks through September. Thus, the microencapsulated baits showed good attractiveness for 10 months over a 2-year period under extremely hot field conditions. (AZ)

In laboratory tests of an attracticide (formulation of gossyplure + permethrin), male pink bollworm moths were killed when exposed to potted plants treated with the material. Plants treated with the attracticide formulation and aged in a greenhouse showed effectiveness through 7-10 days. Potted plants placed in an open field and treated with an airplane showed some effectiveness through 5-7 days. (AZ)

In Arizona, whitefly, _Bemisia tabaci_, adults overwintered on cheeseweed, prickly lettuce, and sunflower. By the end of March, the whiteflies left the weed hosts and became established on squash, watermelon, and cantaloupes. In mid-July, after movement into cotton, whitefly adult populations were highest in cotton fields in areas where these crops had been grown. Populations in cotton in all areas increased after mid-July at an exponential rate, doubling every 6 to 10 days until mid-August in most areas. (AZ)

A test using a boll weevil pheromone-based material, Blockade®, showed that the recommended methodology was inadequate for providing economical control of heavy overwintered weevil populations. When applied with an insecticide, the _Heliothis_ pheromone formulation, Vantage®, reduced oviposition in large field trials. (GA)

Split field comparisons of thiodicarb and flucythrinate revealed that rates higher than the anticipated minimum label rates of thiodicarb are necessary for control of tobacco budworm. A replicated large plot demonstration showed that a tank-mix of chlordimeform and a reduced rate of fenvalerate provided _Heliothis_ control equal to a standard rate of pyrethroid alone. Thiodicarb provided excellent control of beet armyworm in three late-season tests; methomyl and

methamidophos provided adequate control while cypermethrin gave poor control. Monocrotophos proved effective in controlling western flower thrips in tests and demonstrations; acephate also provided adequate control. (GA)

Cypermethrin gave good control of Heliothis spp. and boll weevils when applied by air at 0.06 pound per acre in (1) one quart of vegetable oil, (2) one quart of vegetable oil plus emulsifier plus enough water to make 1 GPA, or (3) in water at 2 GPA total volume. However, cotton aphids built up to damaging levels that required control. Permethrin, fenvalerate, flucythrinate and cypermethrin gave reasonably good control of first instar beet armyworms but failed to control larger larvae. Aerial and ground applications of thiodicarb (0.6 pound per acre) gave good control of all stages of beet armyworms. (LA)

A survey of the Miridae found in the Delta of Arkansas, Louisiana, and Mississippi was completed in 1983. Species of Miridae were collected by sweepnet and beating net from crops and wild plant species at 15 sample locations. Black light trap samples were also taken at 3 locations. A total of 105 species of Miridae representing 46 genera were collected. Thirty-nine species are considered new state records for Mississippi, 10 for Louisiana and 5 for Arkansas. The tarnished plant bug, Lygus lineolaris (Palisot de Beauvois) was the most abundant mirid captured and it was found on 169 plant species representing 36 plant families. (MS)

A series of field experiments were carried out this season to assess interactions between the braconid parasitoid, Microplitis croceipes, and its hosts Heliothis zea and H. virescens. Larvae parasitized in early instars damaged fewer fruits and moved less than larvae parasitized in later instars or left parasite free. Wasp preferences were determined for hosts species and instar using cotton in field cages. Rankings of preferences from most preferred to least preferred instar were 3rd, 4th, 2nd, 1st, 5th. Preference for an instar correlated with wasp development rate in that instar. Searching efficiency was higher in cotton than in early-season host plants. Parasitization was density-independent over the range of densities studied. (MS)

During 1983, the final year of a 3 year study conducted in Mississippi, evaluations were made of the effect of different rates of aldicarb (15G) on cotton arthropod populations. The purpose of the study was to determine if aldicarb can be used in-furrow at rates that will control early-season insects without eliminating predator populations or increasing the incidence of Heliothis spp. damage. Aldicarb treated plots had higher square counts and less Heliothis spp. damage than the check or foliar treated plots. Plots treated with aldicarb at rates of 0.25 and 0.50 pound per acre averaged 24 and 25% fewer plant bugs than the check over the three years. Aldicarb treated plots had fewer beneficials than the check but about 25% more than the foliar treatments averaged over 3 years. (MS)

A biological information transfer system "SUNWASH" that began in 1982 was continued and enlarged during 1983. The area contained approximately 55,000 acres of cotton in Washington and Sunflower Counties. This system enabled the flow of research data from field sampling and trapping programs through the Mississippi Cooperative Extension Service to growers and consultants. (MS)

In small plot (1/2 acre each) replicated tests in 1983 the F_1 Heliothis spp. larval population in Geranium dissectum, the major early-season wild host of Heliothis in the Delta of Mississippi, was reduced an average of 55% with one application of 2,4-D applied at a rate of 1 pound per acre on 4/21; 85.4 and 55.1% with one mowing on 5/5 or 5/19, respectively; 0.0% with treatments of 4 ounces of Elcar® applied on each of 5/19 and 5/26; and 66.3% with 4 ounces of Elcar® applied on each of 5/12, 19, 26 and 6/2. The control of the F_1

Heliothis spp. larval populations in geranium in 1983 in all treatments was considerably lower than that in previous years, especially in 1981. This was probably due to low temperatures and excessive rain during the 1983 test period which adversely affected the activity of the 2,4-D. (MS)

The effectiveness of sterile boll weevils in reducing egg hatch and suppressing populations of native weevils was demonstrated in fields of commercial cotton located in the Mississippi Delta. Two new methods of releasing the sterile weevils were used. In one method the sterile weevils were placed in small paper bags (30 per bag) and were distributed into 3 of the fields at a rate of 10 bags per acre. In the second method, the sterile weevils were suspended in an agar-like solution and dispensed into 3 fields by means of a specially designed pumping system. Egg hatch in the fields in which the weevils were released by the bag method was reduced an average of 60.2%, and 44.7% in fields where the liquid release method was used; hatch in untreated fields averaged 99.0%. The LT_{50} of the released weevils averaged 5 days. Competitiveness of the sterile weevils compared to untreated laboratory weevils averaged 16.7% and 13.6% respectively. (MS)

Research is being conducted to determine the best combination of antibiotics that will maintain a bacteria-free colony of boll weevil for sterilization and release under mass rearing conditions. Field tests are being conducted using the combination of kanamycin sulfate and chloramphenicol. In the laboratory, mortality has been reduced from 60% to 2% at 5 days postradiation. At 10 days postradiation mortality has been reduced from 100% to 50%. (MS)

Weevils reared on the new antibiotic treated diet were irradiated and released into 3 one-acre plots of cotton that contained native weevils. The sterile weevils were released twice a week for a total of 5 releases. The LT_{50} of the sterile weevils was increased from the 5 days seen in the preceding test to 8 days. Significant reductions in egg hatch were noted in all 3 plots and the competitiveness of the sterile weevils compared to native weevils averaged 50.4% (range 29.2-83.5%). (MS)

The "Dynamic Threshold" was developed based on simulation experiments using the Cotton and Insect Management Model developed by researchers at Mississippi State University. As a result of field investigations involving the Dynamic and Current Insect Control (CIC) Thresholds, the CIC Threshold was modified to recommend insecticide treatments sooner after 1st bloom than was previously recommended. Results suggest that early setting cotton fruit (first bloom) are more valuable, in terms of harvestable mass, than late setting cotton fruit (after first open boll). (NC)

Tests in North Carolina indicated that Heliothis spp. eggs were distributed all over cotton plants when moisture stress limited plant growth; eggs were concentrated in the upper third of plants not subjected to moisture stress. Site of oviposition had no effect on survivorship. Proportionally, more larvae of all sizes were found on bolls to which dried corollas remained attached. (NC)

European corn borers (ECB) needed only 24-48 hours to reach large bolls after hatch from egg masses deposited under cotton leaves. Damage by this species was approximately 3X higher in heavily vs. lightly fertilized cotton plots in replicated studies. Scouting for egg masses was impractical; 45 to 120 minutes were required to find one egg mass in moderately (10-15%) infested plots. Ovipositional preferences for several phenological states of field corn, cotton, and cocklebur generally favored corn early and cotton and cocklebur late, with "release" from and the drying of corn critical in this switch. Pix growth regulator had no significant effect on reduction of ECB damage on

late-planted, irrigated cotton in an initial replicated study. In this same test, generally poor control of ECB was obtained with 9 candidate compounds sprayed 4 times late season, as compared to the untreated check; chlorpyrifos + fenvalerate, profenofos, and sulprofos were insignificantly more effective than the other compounds. (NC)

Screening tests confirmed the high efficacy of standard, new and numbered pyrethroids as the compounds of choice where Heliothis zea was the predominant pest. The use of biological insecticides, although conceptually attractive, continued to result in high enough economic Heliothis damage to preclude their recommendation, even in weevil-free areas of North Carolina. (NC)

A new sequential sampling system was evaluated in the field with very satisfactory results. This system was incorporated with existing sequential (Wald's) techniques into a hand held calculator program for use in IPM programs. (OK)

Twenty commercial cultivars were tested for fleahopper preference. There was significant difference but the source of this difference has not been shown. Fifteen commercial cultivars were examined for tolerance to bollworms and as in the past, long-season cultivars were less tolerant than short-season cultivars. (OK)

A temperature growth model for cotton and bollworms was refined. This model is published in Oklahoma research report P-831 (April 1983). (OK)

Overwintering studies for the bollworm showed the highest percent survival ever recorded at this station; some plots had over 80% survival. (OK)

Pheromone trap investigations demonstrated that migrating bollworms arrived in northern Oklahoma about one month later than last year. (OK)

Two insect growth regulators CGA-112913 and CME-13406, when combined with chlordimeform, showed promise for Heliothis spp. control. In laboratory studies CGA-112913 was more effective than CME-13406 against Heliothis zea. Three new pyrethroids (FCR-1272, FMC-54800, and CN-11-3859) were effective against a moderate infestation of Heliothis spp. A new organophosphate insecticide (SC-1069) and DPX-H5249 (chemistry unknown) also showed promise against the Heliothis complex. (OK)

Field tests indicated that fluvalinate provided excellent control of thrips on cotton at an extremely low rate of 0.0125 pound per acre. Profenofos was only slightly less effective and was not significantly different from fluvalinate and the dicrotophos standard. In tests with caged boll weevils, several new compounds including BAY FCR-1272, cypermethrin, and tralomethrin (HAG-107) were quite effective. (TN)

In a cooperative research effort involving ARS laboratories at Stoneville (MS), College Station (TX), Tifton (GA), Beltsville (MD), and Raleigh (NC), augmentative releases of Trichogramma pretiosum Riley were evaluated in replicated tests for effectiveness in managing Heliothis spp. in cotton fields located near Clinton, NC, (final year of a 3-year pilot test). Eight fields (101.2 acres) were aerially treated 7 times between late July and mid-August at a rate of ca. 167,000 parasitoids per acre in each release. Numbers of Heliothis spp. eggs varied considerably in the release fields; densities as high as 49,000 eggs/acre were observed. Egg parasitism rates increased dramatically after the second parasitoid release and were maintained at a average level of ca. 60%. Although the level of Heliothis spp. control did not compare favorably to that afforded by conventional insecticides applied according to North Carolina State University Extension Service recommendations on eight insecticide-control fields (239.7 acres), release-fields had considerably less damage than untreated controls. Much of the Heliothis damage in the Trichogramma-release fields was caused by larvae that hatched from very low egg

numbers between late June and mid-July during a period when releases were not made. An apparent high rate of survival among these early-season larval infestations is attributed to a decimation of natural enemies by azinphosmethyl applications applied for control of overwintered boll weevils. Populations of natural enemies were very low throughout the season in the release fields and thus did not have the impact that is essential for Trichogramma releases to be effective. Although no conclusive evidence has been generated on the effectiveness of using augmentative releases of Trichogramma to manage Heliothis spp. on cotton, it has been amply demonstrated that a Trichogramma parasitoid suitable for field release can be produced and that practical, economical technology is available for the transport and release by aircraft of a fully viable and competitive egg parasite over large crop production areas anywhere in the U.S.A. This readily available technology may have potential in the management of lepidopterous pests on other crops, but it cannot be used effectively in cotton production areas where insecticides are used.

Pheromone traps were operated at numerous locations throughout the Cotton Belt in a cooperative effort to monitor the early season occurrence of the bollworm and the tobacco budworm. The results indicated that the bollworm was detected in Central Texas and the Texas Gulf Coast earlier than in 1982 and its occurrence was associated with winds suitable for moth transport from the south to the north. However, a series of cold fronts which followed apparently precluded any large scale movement of the bollworm into the southcentral part of the U.S.A. comparable to that observed in 1982. Although some movement of the bollworm into the area appeared to occur later, the time difference between the first occurrence of the bollworm and the time when emergence from overwintering was expected was not as great as observed in 1982. It is uncertain what effect the apparent delay had on the development of local bollworm populations throughout the southcentral part of the U.S.A. (TX)

Insect and Crop Conditions

Populations of cotton insects other than the boll weevil were generally light during 1983 in Arkansas. Bollworm populations maintained an overall low status for most of the year. Boll weevil populations were high in several areas of southeast and central Arkansas but were light in northeast Arkansas. The apparent emergence of overwintered weevils well into the summer may have contributed to control problems. The European corn borer caused extensive damage of cotton bolls in a field near corn.

Significant expansion in the overall range of the boll weevil occurred in 1982 and 1983. The most dramatic extension in the boll weevil's range was first reported officially in February 1983 in the state of Sao Paulo in southern Brazil. This occurred in the vicinity of Campinas in an area of major production of upland cotton. By September, infested cotton was reported on 90,000 ha in a zone 250 x 130 km. Meanwhile, a second infestation was found on July 4 in northeastern Brazil in Inga, State of Paraiba. Since then, the weevils have dispersed over a wide area including parts of neighboring States of Rio Grande do Norte and Pernambuco. The greatest concern in Brazil is the possible initiation of infestations in perennial cotton; about 2 million ha. of this type of cotton occurs in the northeast. Taxonomic evaluations indicated the morphological characteristics of both of these populations are similar to the Southeastern host race of the boll weevil, having closest affinity to the Venezuela/Colombia population.

In Arizona, the boll weevil was trapped in most of the cotton growing areas during the winter and early spring of 1983. Heavier catches were recorded from

the central and western portions of the State. Few weevils were found in presquaring cotton and in fields with pin-head squares. However, some fields had high infestations and heavy damage to squares and bolls by mid-summer and chemical controls were applied. Areas with highest infestations are the Poston area of Parker Valley (La Paz County), Arlington-Gillespie Dam area (Maricopa County), and the Texas Hills-Roll area along the Gila River (Yuma County). Areas of infestation in 1983 are not as widespread as in 1982; however, some fields are as heavily infested. Several small fields of late-planted cotton in the Parker Valley have been shredded and plowed under without harvesting by mid-October due to heavy damage by boll weevil, pink bollworm, and Heliothis spp., and near-defoliation by cotton leafperforator.

In California, weevils were trapped during the winter and spring in the Palo Verde Valley (Riverside County), Bard-Winterhaven area (Imperial County) along the Colorado River, and, to a lesser degree, in the Imperial Valley, about 50 miles west of the Colorado River. In the Palo Verde Valley, sufficient weevils were trapped around one field at pin-head square time to initiate a series of diflubenzuron treatments for overwintered boll weevil control. Six applications were made with the last one applied on July 5. No adult weevils or signs of feeding or oviposition were found in the field during the application period. Adult weevils were trapped in the Palo Verde Valley and in the Bard-Winterhaven area during September. Also weevils have been trapped in the Imperial Valley in October in greater numbers and over a larger area than in 1982. However, no infested fields had been found in the Imperial Valley by mid-October.

The 1983 cotton crop in Georgia was planted a little later than usual, but most of the acreage was in the ground before mid-May. Adequate moisture in June produced good squaring rates and ample blooms by the Fourth of July. But then the rain stopped and by mid-July cotton began to suffer. By the end of July, much of the dryland cotton had set only a few lower bolls and shed everything else. Scattered rain early in August allowed some fields to set a short top-crop but dry weather again reduced boll retention.

Several insect pests caused considerable economic loss in Georgia during 1983 -- mostly in cost of control rather than loss in yield. Overwintered boll weevil populations were the highest in a number of years; most growers applied several early sprays for weevils and results were good. Hot, dry weather in July and August caused high mortality in the second, third, and fourth weevil generations, but there were problems with weevils feeding on young bolls.

Thrips infestations in Georgia were moderate to heavy in 1983. Aphids were more of a problem than usual both in seedling cotton and later in the season. Plant bugs were found in many fields and remained a concern through June. Early sprays for weevils and worms helped prevent damage by plant bugs.

The June tobacco budworm outbreak was later and more severe than usual in Georgia; many growers were forced to spray before cotton bloomed. The July tobacco budworm flight, which normally causes the worst cotton insect problem, did not occur until mid-July and then was fairly light. Corn earworms moved to cotton in late July and early August but were only a problem where moisture was adequate and cotton remained attractive.

Fall armyworm infestations were widespread in Georgia but not severe enough to require treatment. Beet armyworm outbreaks in isolated areas required treatment. Western flower thrips were a problem again this year in Georgia; that makes 3 out of the last 4 seasons -- the dry ones. Spider mites reached treatable levels in many fields.

Overwintering boll weevils entered Louisiana cotton fields in record numbers, but were controlled adequately during the growing season with

recommended insecticides. Heliothis species were light through July and light to moderate in August and September, with the highest numbers in irrigated cotton. Cotton aphids were high in spotted fields. Spider mites required control in August in some fields.

Several male pink bollworm adults were captured in gossyplure-baited traps near Stoneville, MS, but there was no evidence of infestations in surrounding cotton fields.

Insect damage to the 1983 late planted cotton crop in North Carolina was generally lighter than usual. Heliothis pressure was approximately 7-10 days late across most of the State (late July to mid-August from south to north), with the bollworm again the predominant species. Some early (late June to mid-July) spot spraying was needed for an earlier (normally sub-economic) generation of tobacco budworms and bollworms. Late season moth oviposition and bollworm establishment were light, mostly because of the unattractive, fruit-shedding plants resulting from hot, dry conditions. Insecticide applications for bollworm in northern North Carolina ranged from approximately 0 to 5, with a mean of 2. Applications for boll weevil-bollworm in southern North Carolina ranged from approximately 7 to 16, with a mean around 12, excluding diapause treatments applied by Eradication personnel.

Economic boll weevil damage was nonexistent in the core area of the Boll Weevil Eradication Area, although a few fields in the Buffer Zone received substantial damage (20-30% loss of large bolls). All acreage from southern North Carolina to the Georgia-South Carolina border was treated with a series of diapause applications beginning on August 22, marking the beginning of the expansion of the Eradication Program into this area.

Increased incidence of plant bugs in North Carolina as well as very high populations of western flower thrips on mid-season cotton was noted in 1983. European corn borer (our number three pest in 1982) damage was down considerably, reversing a 4 or 5 year upward trend.

Fall armyworms were also little more than infrequent visitors to most North Carolina cotton fields. Rounding out the picture, spider mites (mid- and late-season) and aphids (late-season) were present in higher than usual numbers, but caused little general economic concern.

Excessive moisture and cool weather during May and June delayed planting of the 1983 cotton crop in Oklahoma. Most of the cotton in southwest Oklahoma was three weeks behind schedule. Drought conditions during July, August, and September reduced the yield potential of dryland cotton. Irrigated fields were able to produce an average yield due to favorable growing conditions during September.

Scouting schools were conducted by Extension personnel to educate consultants, aerial applicators, and producers in proper cotton pest management techniques. Extension personnel assisted the Oklahoma Cotton Improvement Association (OCIA) with a cotton pest management program. Ten scouts and a field supervisor were employed, trained, and supervised during 1983. There were approximately 5,500 acres of cotton scouted as part of the OCIA program.

Fifty-two boll weevil traps were placed adjacent to weevil overwintering sites in five counties across southwest Oklahoma. The average number of boll weevils captured per trap in 1983 was 323 compared to 12 during 1982 and 4 during 1981. Boll weevil controls (trap crop and pin-head application) were employed in traditional weevil areas. Although early season problems were reduced due to the late planting, boll weevils continued to increase resulting in the majority of irrigated cotton being sprayed 4 times. Crop lateness reduced thrip problems; however, some fields were treated. Fleahoppers were abundant during July with some fields being treated twice.

Hot, dry weather favored the development of spider mites, and these pests were widespread across southwest Oklahoma. In most cases, the spider mite buildup was noted in fields treated with synthetic pyrethroids. Most of the fields infested by mites were treated twice during August and early September. The western flower thrips reached damaging populations during late August and September, justifying insecticidal control in some fields. Lygus bugs caused some damage in a few fields in east central Oklahoma.

Populations of the bollworm/tobacco budworm complex in Oklahoma were extremely light in dryland cotton. Light bollworm pressure occurred in irrigated fields during August and early September resulting in fields being sprayed an average of three times. An extremely small number of tobacco budworms was found throughout the season.

In South Carolina during 1983, boll weevil infestations were extremely heavy in many areas, while *Heliothis* spp. infestations were light to moderate. Populations of western flower thrips reached levels as high as 100 or more per bloom in many areas. Yields of cotton in South Carolina were generally reduced by prolonged drought and high temperatures.

Table 1.--Estimated reduction in 1983 cotton yields resulting from insect damage.[1/]

Loss attributable to--[2/]	State								
	AL	AZ	AR	CA	FL	GA	LA	MS	MO
Boll weevil:									
Percent	8.2	0.8	2.9	0.0	7.6	4.0	4.6	4.0	0.0
Bales	14.76	5.30	9.28	0.00	0.93	4.8	28.84	36.00	0.00
Bollworm-tobacco budworm:									
Percent	3.0	1.0	1.1	0.1	6.8	3.0	3.2	2.0	1.0
Bales	5.40	7.00	3.52	1.98	0.84	3.60	17.28	18.00	0.73
Cotton fleahopper:									
Percent	0.0	<0.1	0.0	0.0	0.0	0.0	0.2	<0.1	0.0
Bales	0.00	0.14	0.00	0.00	0.00	0.00	1.24	0.01	0.00
Lygus spp. and other plant bugs:									
Percent	0.2	1.2	0.8	1.2	0.2	1.0	0.3	<0.1	1.0
Bales	0.36	8.45	2.56	23.76	0.54	1.20	1.35	0.06	0.73
Cotton leafperforator:									
Percent	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bales	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pink bollworm:									
Percent	0.0	3.5	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Bales	0.0	24.60	0.00	3.96	0.00	0.00	0.00	0.00	0.00
Spider mite:									
Percent	2.0	0.1	0.2	1.8	0.3	0.5	0.6	<0.1	<0.1
Bales	3.60	0.70	0.64	35.64	0.04	0.60	3.24	0.09	0.01
Thrips:									
Percent	0.1	0.0	0.3	3.0	0.2	0.0	0.3	<0.1	<0.1
Bales	0.18	0.00	0.96	59.40	0.03	0.00	1.62	0.03	0.04
Others:									
Percent	0.1[11]	0.6[4,5,11]	0.0	0.0	0.6[3]	0.6[3,4,12]	0.2[9]	<0.1[3,4,7-11]	<0.1
Bales	0.18	3.87	0.00	0.00	0.07	0.73	1.08	0.02	0.04
Total percent loss	13.6	7.4	5.3	6.3	15.7	9.1	9.4	6.5	2.3
Total bale loss	24.48	50.41	16.96	124.74	2.45	10.93	54.65	54.21	1.55
Control cost/acre($)[13/]	59.96	74.00	24.31	18.78	135.92	52.00	57.75	45.91	7.00
Yield in bales[14/]	180.0	704.0	320.0	1980.0	12.3	120.0	540.0	900.0	73.0
Acres harvested (x1000)	215.0	317.5	310.0	965.0	9.5	115.0	410.0	675.0	93.0

See footnotes at end of table.

Table 1.--Estimated reduction in 1983 cotton yields resulting from insect damage--Continued.

Loss attributable to--	State							No. bales lost all States	Pct. loss, avg. all States
	NM	NC	OK	SC	TN	TX	VA		
Boll weevil:									
Percent	0.0	3.0	9.0	6.0	3.0	2.9	0.0		2.5
Bales	0.00	1.35	12.60	3.30	4.50	66.99	0.0	188.65	
Bollworm-tobacco budworm:									
Percent	2.0	6.5	6.0	4.9	2.0	2.2	4.0		1.7
Bales	1.46	2.93	8.40	2.70	3.00	50.71	0.01	127.56	
Cotton fleahopper:									
Percent	5.0	0.0	1.0	0.0	0.0	1.0	0.0		0.4
Bales	3.65	0.00	1.40	0.00	0.00	24.19	0.0	30.63	
Lygus spp. and other plant bugs:									
Percent	7.0	0.5	0.0	0.8	0.4	0.4	0.0		0.7
Bales	5.11	0.23	0.00	0.44	0.60	9.30	0.00	54.69	
Cotton leafperforator:									
Percent	0.0	0.0	0.0	0.0	0.0	0.0	0.0		I
Bales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	
Pink bollworm:									
Percent	1.0	0.0	0.0	0.0	0.0	0.1	0.0		0.4
Bales	0.73	0.00	0.00	0.00	0.00	2.56	0.00	31.85	
Spider mite:									
Percent	1.0	0.0	0.5	0.5	0.1	0.1	3.0		0.6
Bales	0.73	0.00	0.70	0.28	0.15	2.09	0.01	48.52	
Thrips:									
Percent	4.0	0.5	0.3	0.6	0.1	1.0	2.0		1.2
Bales	2.92	0.23	0.35	0.33	0.15	22.33	<0.10	88.57	
Others:									
Percent	0.0	1.0	0.3	<0.1[3,4]	0.0	0.1	0.0		0.1
Bales	0.00	0.47	0.35	0.01	0.00	3.26	0.00	10.08	
Total percent loss	20.0	11.5	17.1	12.9	5.6	7.8	9.0		7.6
Total bale loss	14.60	5.21	23.80	7.06	8.40	181.43	0.02	580.90	
Control cost/acre($)[13/]	15.00	57.00	38.00	80.00	8.50	9.66	25.00		
Yield in bales[14/]	73.0	45.0	140.0	55.0	150.0	2326.0	0.2		
Acres harvested (x1000)	60.0	59.0	300.0	69.0	215.0	3322.8	0.3		

See footnotes at end of table.

[1] All bale figures in table x 1,000. Estimated by research, extension, and others based on Statistical Reporting Service December Report. I=insignificant.
[2] Losses indicated were those incurred even with recommended control programs.
[3] Fall armyworm (Spodoptera frugiperda (J. E. Smith)).
[4] Beet armyworm (Spodoptera exigua (Hubner)).
[5] Stink bugs (Euschistus spp.).
[6] European corn borer (Ostrinia nubilalis (Hubner)).
[7] Yellowstriped armyworm (Spodoptera ornithogalli (Guenee)).
[8] Grasshoppers (Schistocerca americana (Drury)).
[9] Cotton aphid (Aphis gossypii Glover).
[10] Cutworms (Agrotis spp.); (Feltia subterranea (F.).
[11] Whitefly (Trialeurodes abutilonea (Haldeman)).
[12] Western flower thrips (Frankliniella occidentalis (Pergande)).
[13] Average control cost for all States--$44.30/acre.
[14] Total yield for all States--7618.5 bales; total acres harvested--7,136,100.

INTRODUCTION

This report of the 37th Annual Conference of State and Federal workers is concerned with cotton-insect research and control. Research and extension entomologists and associated technical workers from 15 cotton-growing States, the United States Department of Agriculture, National Cotton Council of America, Cotton Incorporated, Plains Cotton Growers Inc., the Environmental Protection Agency (EPA), National Agricultural Chemical Association, and industry met to review the research and experiences of the previous year and to formulate guiding statements for control recommendations in 1983. The chief purpose of the Conference is to enable the exchange of information that may be useful in planning further research, survey, and extension work, and to make the results of research available to others.

The report presents information of value to (1) industry in planning production programs, (2) State and Federal research workers in planning research programs, (3) extension entomologists in bringing to the attention of growers and other interested groups the control recommendations for their States, (4) teachers of entomology in the various colleges and universities, and (5) consulting entomologists. It is also widely used in foreign countries in connection with the development of cotton-insect control programs.

Agreement on overall management philosophy may be expected; however, complete standardization of recommendations throughout the Cotton Belt is not possible because pest problems will vary with the region or locality. Cotton growers in the respective states should follow the recommendations contained in the State "Guides for Controlling Cotton Insects" and the advice of qualified entomologists familiar with local problems.

Determining the species and abundance of various insects and the specific injuries inflicted upon the cotton plant is important in insect control. Knowledge of the life history and habits of the insects, the growth and fruiting characteristics of cotton plants, and the environmental relationships that exist between the plants and insects yields additional information basic to an evaluation of the economic insect situation involved. Each control measure used should be a part of an integrated control program, utilizing to the fullest extent wherever possible cultural, physical, mechanical, biological, legal, and natural controls. However, when the level of infestation of an insect or group of insects approaches the economic threshold, chemical control measures should be applied to prevent damage to the cotton crop. Insecticides, dosages, formulations, and timing schedules should be selected to solve existing problems without creating new ones.

In making recommendations for the use of insecticides, entomologists should recognize their responsibility with regard to hazards to the public. (See "Insecticides and Miticides.") The insecticide industry has a great responsibility to the cotton grower in making available adequate supplies of recommended materials that are properly formulated. Sales programs should be based on state or area recommendations.

Research results on cotton-insect control obtained by the United States Department of Agriculture and the State experiment stations are extended to the cotton industry by the Cooperative Extension Service in each State. It is the responsibility of each individual farm operator to make decisions concerning the control of cotton insects. This may be done by the producer or the job can be delegated to someone else. (See "Determining the Need for Chemical Control.")

PROGRESS IN INSECT REARING

Research on cotton insects was hampered for many years because of difficulties encountered in rearing them in the laboratory. It was difficult, as well as expensive, to rear insects in needed numbers on their hosts. Major breakthroughs in research were facilitated through the ability to mass-rear the various insects on artificial diets. Progress in insect rearing enhanced research on detection, migration, and insecticide evaluation as well as on the sterile-male release technique.

Pink bollworm.--The first phytophagous insect to be reared on an artificial diet was the pink bollworm, in the early 1950's at the USDA Cotton Insects Research Laboratory, College Station, TX. The artificial diet developed for this insect has served as the basic diet for many phytophagous insects now being mass-reared in the laboratory. The pink bollworm is mass-reared at the rate of 13 - 17 million per week in the Pink Bollworm Rearing Facility, Animal and Plant Health Inspection Service (APHIS) at Phoenix, AZ. The insects are made sexually sterile and are released in the San Joaquin Valley of California at selected locations where migrant moths had been captured. The releases apparently prevented the establishment of infestations by occasional migrants from the Imperial and Coachella Valleys until 1977, when a few larvae were found in cotton bolls. No additional larval infestations were found until 1980. In the off-season, sterile moth releases were made for several years to wild cotton in the southern tip of Florida for suppression of pink bollworm populations on that host. For many years populations were suppressed by manual destruction of wild cotton plants, which was a costly and almost impossible task. This new pest management technique was made possible through the development of mass-rearing procedures for the insect.

Boll weevil.--In the early 1960's boll weevils were reared on artificial diets at the USDA Cotton Insects Research Laboratory in College Station, TX. Improvements in rearing were made at that laboratory and at the Baton Rouge, LA, and Florence, SC, USDA laboratories. Progress in mass rearing the insect was made with the establishment of the USDA Boll Weevil Research Laboratory on the Mississippi State University campus in 1961. After it became apparent that the insect could be reared and sterilized in sufficient numbers, it was deemed that a Pilot Boll Weevil Eradication Experiment should be conducted to determine whether it was technologically and operationally feasible to eradicate the boll weevil. With an appropriation of more than $0.5 million from the Mississippi Legislature, the Robert T. Gast Rearing Laboratory was built on the Mississippi State University campus. Problems with the rearing facililty, as well as with rearing procedures, prevented production of the numbers of insects needed for sterile-male releases; however, the facility made a significant contribution to the success of the experiment. Subsequently, the rearing procedure has been mechanized, the vigor of weevils increased, and sterilization procedures improved. The facility provided 11.2 million sterile boll weevils during the Boll Weevil Eradication Trial initiated in 1978 and completed in 1980 in North Carolina and Virginia. The ability to mass produce healthy, fully-competitive boll weevils should be important if eradication of the boll weevil from the United States is undertaken, and if the release of sterilized boll weevils is included among the different control techniques that would be used.

Bollworm.--Diets and techniques for rearing the bollworm also were developed at the USDA Cotton Insects Research Laboratory in College Station, TX. Though small cultures were reared at several laboratories, the major thrust in mass rearing was done at the USDA Southern Grain Insects Laboratory at Tifton, GA. A mechanized system for mass rearing the insect was developed at this laboratory.

Tobacco budworm.--In 1976-77, a large scale rearing program was developed at Stoneville, MS, for the tobacco budworm and its sterile *Heliothis* hybrid backcross (BC_n♀ x *H. virescens*♂) from the intercross *H. virescens*♂ x *H. subflexa*♀.

Stoneville began shipments of tobacco budworms and backcross pupae to St. Croix, Virgin Islands, in 1978 for use in a program to control the tobacco budworm through releases of the sterile *Heliothis* hybrid. During the fall of 1980, production for this program reached a maximum, with over 5 1/2 million backcross pupae being shipped. Total production of backcross and tobacco budworm pupae for this program was well over 8 million. Shipments of 1,000 tobacco budworm pupae per week for monitoring purposes are continuing at present.

Stoneville also reared an additional 2 million backcross pupae during the spring of 1981 and 1982 for use in research tests conducted at Stoneville and Mississippi State University.

In addition to the above, Stoneville also supplies tobacco budworm eggs and pupae to approximately 40 researchers in private industry, State universities, and USDA. This is made possible through a cooperative agreement funded by the Cotton Foundation of Memphis, TN.

Lygus bugs.--More than 15,000 adult *Lygus hesperus* per week have been reared for a sustained period using an artificial diet rearing system. Large numbers of two *Lygus* nymphal parasites, *Leiophron uniformis* and *Peristenus stygicus*, and an egg parasite, *Anaphes ovijentatus*, are being reared on *Lygus*.

Miscellaneous Lepidoptera.--Occasional phytophagous pests of cotton such as the saltmarsh caterpillar, beet armyworm, cabbage looper, fall armyworm, etc. can also be easily reared in the laboratory on artificial diets for use in research.

Beneficial insects.--The green lacewing *Chrysopa carnea* has been mass-reared in the laboratory on diets consisting of natural host eggs for larvae, and a mixture of sugar and Food Wheast® for adults. Encouraging results were obtained in research on rearing the predator on an artificial diet. Some progress has also been made in rearing *Trichogramma pretiosum*, *Campoletis perdistinctus*, *Cotesia marginiventris*, *Eucelatoria bryani*, and *Microplitis sonorensis* on artificial diets. The research on *Trichogramma* has been greatly facilitated by the recent discovery and identification of a powerful oviposition stimulant which allows easy collection of large numbers of eggs for use in studies of diets. Two diets have been developed for rearing fertile *Geocoris* spp. adults; however, yields are low.

COTTON-INSECT CONTROL METHODS

Entomologists have made considerable progress in developing methods for controlling cotton insects. An insect pest management system was developed in Arkansas in the 1930's and 1940's based on scouting, spot dusting, and early maturity of the cotton crop. In the late 1940's and 1950's, a system of early-season insect control on a community-wide basis was developed in Texas. In the

1970's, a Heliothis spp. population management system on a community-wide basis was developed in Arkansas. In Texas, the development and use of short-season rapidly fruiting and determinate cotton genotypes, along with uniform planting, area-wide post-harvest stalk destruction, and field scouting, has substantially reduced the insect problems. It is extremely important that various insect control practices be integrated into a system such as Integrated Pest Management. However, it must go beyond the control of various pests such as insects, diseases, nematodes, and weeds and encompass the best production practices for all crops grown within an ecosystem.

Cultural Practices

Certain cultural practices reduce insect problems and may give adequate control without the use of insecticides. Several of these practices can be followed by every cotton grower, whereas others are applicable only to certain areas and conditions. Growers following these practices should continue to make careful observations for insects and apply insecticides only when needed.

Early stalk destruction.--Problems associated with the boll weevil emphasize the urgent need for early destruction of cotton stalks. The destruction or killing of cotton plants as early as possible before the first killing frost minimizes population buildup and reduces the overwintering population of boll weevils. The earlier the weevil population is deprived of its food supply the more effective this measure becomes. Early stalk destruction, especially over community-wide or county-wide areas, has greatly reduced the boll weevil problem the following season, especially in the southern part of the Cotton Belt.

Early stalk destruction and burial of infested debris are generally the most important practices in cultural control of the pink bollworm. Modern shredders facilitate early stalk destruction and complete plowing under of crop residues. The shredding operation also kills a high percentage of pink bollworms left in the field after harvest. The flail shredder is recommended over the horizontal rotary shredder for pink bollworm control. Plowing under crop residue as deeply as possible after the stalks are cut will further reduce survival of the pink bollworm. The use of these machines should be encouraged to control both the boll weevil and pink bollworm. Early stalk destruction can also reduce the potential number of overwintering bollworms and tobacco budworms.

Stub, volunteer, or abandoned cotton.--Stub, volunteer, and abandoned cotton contributes to insect problems because the stalks and undisturbed soil provide a place for insects to live through the winter. This is especially true for the cotton leafperforator, pink bollworm, and boll weevil. Volunteer cotton is also the principal winter host for the leaf crumple virus of cotton in the southwestern desert areas and for its whitefly vector.

Planting.--Uniform planting of all cotton within a given area during a short period of time is desirable. A wide range in planting dates extends the fruiting season, which tends to increase populations of the boll weevil, pink bollworm, and possibly other insects. Planting during the earliest optimum period for an area also makes early stalk destruction possible. Excessively thick stands are attractive to Heliothis spp. and plant bugs and should be avoided.

Row spacing.--Cotton is usually planted in various row patterns and widths. Insects and spider mites that feed on weeds allowed to grow in wide middles may move into the cotton when such weeds are destroyed by cultivation. The skip-row practice necessitates modification of ground application equipment. Applications by airplane become more expensive because the entire field must be treated and only a part of it is planted to the crop. Although yields may not be reduced, skip-row planting may delay maturity and increase the period the crop must be protected from insects.

Narrow-row spacing, including drilling with a grain drill or broad casting, has been researched extensively. The advantage lies in a short production season, which reduces insect problems. The system has not been generally accepted because (1) heavy demands are placed on moisture and nutrients in a short period of time, and (2) once-over harvest by pickers continues to pose problems and stripper harvesters are not adapted to all parts of the Cotton Belt. Such a system requires aerial application of insecticides. Without cultivation, chemical weed control may be inadequate for control of alternate hosts of certain insects and spider mites.

Varieties.--Varieties of cotton that bear prolifically, fruit early, and mature quickly may set a crop before the boll weevil and other insects become numerous enough to require prolonged treatment with insecticides. This is especially true when other cultural control practices are followed. Growers should plant varieties recommended for their particular area. Cotton breeders are working with entomologists to develop varieties resistant to several cotton insects. Nectariless varieties that offer some degree of resistance to plant bugs are commercially available. So called short-season or early-maturing varieties are grown in Texas.

Soil improvement.--Fertilization, crop rotation, and green manure crops are good farm practices and should be encouraged. The increased plant growth that usually results from these practices may also prove attractive to some pests necessitating closer attention to their abundance and control. The potential higher yields will give greater returns from the use of insecticides. Overfertilization, especially with nitrogen, may unnecessarily extend the period during which insecticidal protection is necessary. Likewise, reduced growth and delayed maturity may result from nutritional or moisture imbalance, but these factors should not be confused with insect damage.

The fact that a number of insects and spider mites attack legumes and then transfer to cotton should not discourage the use of legumes for soil improvement or crop rotation. Insect pests may be controlled on both crops.

Irrigation.--Irrigation must be used to produce the crop in arid areas and is used to supplement moisture during periods of drought in the rainbelt. Rank growth and a longer fruiting period complicate insect control, and the disadvantages must be balanced against expected yield increase and fiber quality. Judicious use of water must be exercised in producing the crop.

Other host plants of cotton pests.--Cotton fields should be located as far as is practicable from other host plants of cotton insects. Some control measures should be applied to other hosts such as safflower in California to prevent migration to cotton. Thrips breed in onions, potatoes, carrots, legumes, small grains, and some other crops. They later move in great numbers into adjacent or interplanted cotton. Beet armyworms, garden webworms, lygus bugs, stink bugs, variegated cutworms, western yellowstriped armyworms, and

other insects migrate to cotton from alfalfa and other plants. The cotton fleahopper migrates to cotton from horsemint, croton, and other weeds. Spider mites spread to cotton from many weeds and other host plants adjacent to cotton fields.

Overwintering areas.--The boll weevil hibernates in well drained, protected areas in and near cotton fields. Spider mites overwinter on low growing plants in or near fields. Pest breeding weeds along turnrows and fences or around stumps, as well as scattered weeds in cultivated fields, should be eliminated with herbicides or by using cultural or other methods. General burning of ground cover in woods is not recommended. Since ground cover and weeds serve as hibernating sites for many parasites and predators, the detrimental effects on beneficial insects of indiscriminate destruction of weeds by burning and tillage are obvious.

Seed cotton scattered along turnrows, loading areas, and roadsides serves as a source of pink bollworm carryover to the next crop. Care should be taken to see that these areas are cleaned up. To minimize this hazard, trucks, trailers, and other vehicles in which the seed cotton is being hauled to the gin should be covered.

Gin-plant sanitation should be practiced to eliminate hibernating quarters of the boll weevil and pink bollworm. In areas where pink bollworms occur, State quarantine regulations require that gin trash be run through a hammer mill or fan of specified size and speed, composted, or given some other approved treatment.

Quarantine regulations require certification of mechanical cotton pickers and strippers moving from pink bollworm infested to noninfested areas.

Insect Attractants

Boll weevil.--Laboratory research established that the male boll weevil produces a pheromone that is attractive to both males and females. The pheromone was identified as a mixture of four terpenoid compounds. Grandlure, the synthetic pheromone, has been available commercially for more than ten years. Three controlled release formulations are also available, one developed by USDA/ARS and two by private industry.

Grandlure-baited traps have been used extensively across weevil-infested areas of the Cotton Belt for survey and detection. They are considered indispensible in eradication programs because of their sensitivity in detecting low-level populations of boll weevils. In some parts of the country trap capture indices are used to help make pest management decisions.

The development in in-field traps, those that can be used within fields without interfering with cultivation, has provided a tool with potential for use in population suppression or elimination programs. Another management technique with good potential is the treatment of alternate strips of cotton with grandlure to attract overwintered boll weevils, which can then be killed with insecticides applied to the baited strips. If weevil populations are low, such treatments may prevent injurious infestations in the remainder of the field for the season.

Grandlure was registered by EPA in 1979 for use in managing populations of the boll weevil.

Pink bollworm.--It was determined in the mid-1960's that the female pink bollworm moth emitted a volatile chemical that attracted males. Eventually (1978) the pheromone (gossyplure) was identified and synthesized. Gossyplure is

available from different commercial sources and is extensively used in survey, detection, and population suppression programs. It is being used commercially as a confusant to prevent the males from locating the females. Information obtained from traps baited with gossyplure is used to time insecticide applications for control of pink bollworms in the Imperial Valley of California. Gossyplure is registered by EPA for managing populations of the pink bollworm.

Tobacco budworm and bollworm.--Females of the tobacco budworm and bollworm produce powerful sex pheromones to lure males of their respective species for mating. Two major components of the pheromone of the female tobacco budworm, were initially identified, synthesized, and marketed under the name virelure. Subsequent research established that the natural pheromone of the tobacco budworm was a blend of seven components. A comparable four-component sex pheromone of the bollworm was also isolated and identified. All the chemical components of the pheromones of these two species have been synthesized and are readily available from different commercial suppliers. In addition, slow release formulations of different blends of pheromone components can be obtained commercially for use in different research or management programs.

The availability of synthetic pheromones of the two species makes possible research on potential methods for population measurement and suppression. Among the methods suggested for use of these materials are 1) eliminating males by trapping or dispensing the attractant on an insecticide treated substrate, 2) luring the males to a substrate treated with chemosterilants, or 3) saturating an environment with the pheromone and thus interfering with the mating orientation of the males. These pheromones are now used primarily in traps to monitor populations of these species. Excellent progress has been made in using trap catch data in computer-based population models to aid in predicting outbreaks of the pest and in making decisions relating to management strategies. A simple inexpensive wire-cone trap requiring no electrical power facilitates simple and efficient monitoring of adult male populations of *Heliothis* spp. with formulations of the synthetic pheromones.

Genetic Control

Research on the control of cotton insects through different kinds of genetic manipulation has emphasized the sterile-insect release approach that was so successful against the screwworm fly, *Cochliomyia hominivorax* (Coquerel). In this approach large numbers of insects are reared and exposed to ionizing irradiation or to chemosterilants to induce sterility; then they are released among native populations at sufficient ratios to insure a high proportion of sterile matings. Development of this technique includes devising methods for rearing and sterilizing large numbers of insects with minimum effect on their competitiveness in securing mates, for shipping them from the rearing facility to release sites and releasing them so that they disperse among the native population, and for monitoring the effectiveness of the program. Frequently, preliminary applications of other population reduction measures, such as insecticides, are needed to reduce native populations to levels low enough so that an effective overflooding ratio can be achieved.

Boll weevil.--Much research has been conducted on sexually sterilizing the boll weevil. Initial studies indicated that sterilizing doses of gamma irradiation reduced competitiveness and resulted in high mortality. Similar results were obtained with some of the chemosterilants. The current method of choice for sterilizing both sexes involves a combination of irradiation and chemical treatment with an insect growth regulator such as diflubenzuron. This

treatment sterilizes both sexes without severely impairing the competitiveness of the male. This method of sterilization was used for limited evaluations of the sterile-male technique in the recently-completed Boll Weevil Eradication Trial conducted in North Carolina. Ongoing research is directed to further improvements of the sterilization procedure; however, the sterile-male technique is not included as a component of the present expanded effort to eliminate the boll weevil from North and South Carolina.

Bollworm and tobacco budworm.--A great deal of research has been done on methods of sterilizing *Heliothis* spp. and on the effects of such procedures on sexual competitiveness. Gamma irradiation has been pursued most extensively because it is relatively easy to use and presents minimum environmental hazards when proper equipment is used.

A limited field test of this method against the bollworm, conducted on St. Croix, U.S. Virgin Islands, in the early 1970's, was not successful because of problems with rearing. More extensive tests were conducted on the same island in 1972-74. The results of these tests indicated that released mass-reared insects, whether irradiated or not, competed poorly for native mates, especially the males.

Hybrids were produced in the laboratory by crossing *Heliothis virescens* males and *H. subflexa* females. Males from these crosses were sterile and the females were fertile. These females, when mated to normal *H. virescens* males, produced sterile males and fertile females through subsequent backcross generations. This technique has potential to suppress or eliminate populations through male sterilization by releasing these females into the natural population. A pilot test to evaluate and perfect the technique was initiated in late 1977 on the island of St. Croix, U. S. Virgin Islands. When backcross females were released on the island, infusion of the sterility factor into the native population was obtained at some distance from a central release point. About 50 percent of all males captured on the Island two generations after releases made in November and December 1979 on the western one-third of the island were backcross (sterile) males. More than 20 percent of the males were backcross males for eight generations after release. A full release program was initiated in September 1980. Four separate releases of backcross insects, with the last one being an all-island release at a rate of 9 backcross:1 wild, resulted in a backcross frequency in the populations on the island of about 95 percent for several months postrelease. Comparison of postrelease populations on St. Croix with those of preceding years on that island and with those of a neighboring island, Vieques, demonstrated suppression of the population with the sterile-male release. In early 1982 the frequency of backcross males in the wild was 95 percent; however backcross frequency slowly declined to about 50 percent later in the year.

Pink bollworm.--Gamma irradiation sterilization of pink bollworm adults has been studied at length and doses have been reduced to 20 krd, which has improved competitiveness of reared insects with wild insects. The pink bollworm was mass-reared in Brownsville, TX, in 1968 and 1969 and since then in the Pink Bollworm Rearing Facility, Animal and Plant Health Inspection Service (APHIS), USDA, Phoenix, AZ. Migrants from the Imperial and Coachella Valleys, as well as from other southern desert valleys and possibly Mexico and Arizona, have been detected in relatively low numbers in certain localities of the San Joaquin Valley in California each year since 1967. Sterile moths have been released in these locations each year since 1968. Approximately 100 million were released

annually from 1970 through 1973, but virus infection of the rearing colony reduced the numbers released in 1974. Moth releases, which included some reared by private contractor, have increased as follows: 155 million in 1975; 194 million in 1976; 412 million in 1977; 456 million in 1978; 641 million in 1979; 542 million in 1980; 804 million in 1981; 789 million in 1982; and 594 million in 1983. There was no contract for rearing in 1983. The releases apparently prevented establishment of infestations in this important cotton producing valley until a large number of storm-carried native moths were trapped late in the 1976 season. Large numbers of native moths were also trapped in 1977 (7,402). A few larvae found in bolls indicated a low-level infestation occurred in the San Joaquin Valley. Sterile insect releases during the growing seasons have been continuous through 1983. No additional larvae were found until 1980 when single larvae were found in each of two counties on the valley floor and seven were found in an area proximal to but outside the valley proper. Larvae were also detected in the latter location in 1981. No larvae were found in 1982 but were again detected in one location on the valley floor in 1983. Sterile insect releases must continue in the San Joaquin Valley until the pest is eliminated or reduced to very low levels in the southern desert valleys so it will no longer migrate to the San Joaquin Valley.

Host Plant Resistance

In the early days of boll weevil control, when effective insecticides were not available, emphasis was given to cultural controls and early maturing cotton varieties, which made possible the production of a crop before the boll weevil could build up extremely high populations. With the advent of better insecticides and needs for higher yields, management practices exploited the full season potential of varieties grown in the rain belt and the irrigated areas of the west. Such production practices favored the boll weevil and pink bollworm and, though good yields were produced with the intensive use of insecticides, large populations diapaused in the fall, enhancing survival for infesting the subsequent crops and necessitating repetition of the control cycle year after year.

Boll weevil.--When resistance to the organochlorine insecticides developed in the boll weevil in the mid-1950's, research attention was intensified in the development of alternative methods of controlling the boll weevil and other cotton insects. Though considerable effort was expended, progress in the development of varieties resistant to the boll weevil was slow. In the 1970's, research results suggested that frego-bract cottons, in which the bracts are distorted and do not envelop the bud as in normal bract cottons, could reduce boll weevil oviposition by 50 percent or more when compared with normal bract varieties. However, the reduction in oviposition has been considerably less in more realistic situations where the varieties were grown under "no choice" situations. Although Frego bract cottons are more susceptible to lygus bugs than normal bract cottons, breeders are making progress in solving the problem.

Some short-season determinate cotton varieties are now grown extensively in Texas and have shown promise in reducing late-season insect damage, especially by the boll weevil. They also may help alleviate some of the damage caused by *Heliothis* spp. by maturing before the damaging late-season population peaks occur. Fast fruiting cultivars adapted to most of the rain belt have been developed, but production systems to exploit them have not been widely adopted.

Bollworms.--The development of cotton varieties resistant to the tobacco budworm and bollworm has centered on three morphological/physiological characters of the cotton plant and on the development of early-maturing, determinate types of cotton that set the bulk of their fruit 2 to 3 weeks earlier than the non-determinate cottons that are usually grown commercially. Research is also in progress to develop cotton varieties resistant to the cotton fleahopper, plant bugs, and the boll weevil. Success in these efforts would help alleviate the *Heliothis* spp. problem by reducing the insecticide applications for the former pests, thus conserving the natural enemies of *Heliothis* spp.

The first of the morphological characters is lack of nectaries. Normal cottons have extrafloral nectaries on leaves and fruiting forms. The absence of these structures deprives *Heliothis* spp. adults of an important source of food when and where alternate food sources are not available. In controlled tests, the absence of extrafloral nectaries (nectariless cotton) resulted in at least 40 percent reduction in egg deposition and reduced longevity of adults.

The second morphological character measurably reducing populations of *Heliothis* spp. is a smooth (glabrous) plant surface. Commercial cottons have 2,000 to 5,000 trichomes per square inch on the small terminal leaves and buds, which are the preferred oviposition sites of *Heliothis* spp. Tests of glabrous stocks with less than 200 trichomes per square inch have demonstrated a reduction in egg deposition by as much as 50 percent.

The third character showing impact on *Heliothis* spp. populations is a high level of gossypol in the flower buds (squares). Gossypol content in buds of commercial cotton is about 0.5 percent, which affects larvae very little. However, research has shown that larval mortality of as high as 50 percent may occur when the gossypol level is 1.2 percent or higher.

Studies in field cages with cotton strains in which all three characters have been combined showed that populations of the tobacco budworm increased about onefold in two generations. Those on glabrous plus high gossypol cotton or nectariless cotton plus high gossypol cotton increased twofold, while populations on commercial cotton increased about tenfold. In field tests, a glabrous cotton suppressed a *Heliothis* spp. larval population 68 percent compared with the population on commercial cotton, and cottons with both the glabrous and high gossypol characters reduced larval populations 60 to 80 percent. In field tests with advanced strains, one strain with the glabrous-high gossypol combination yielded more seed cotton per acre than did a commercial variety.

Cotton fleahopper.--Cottons with the glabrous character apparently are more sensitive to fleahopper attack than are most hirsute strains and, despite lower infestation levels, suffer greater damage.

Cottons with the high gossypol character or those with this character combined with other resistant characters confer some resistance against the cotton fleahopper, and they have produced yields above those of current commercial varieties.

Lygus bugs.--There is evidence that the nectariless character in cotton can reduce reproduction of lygus bugs, with considerably fewer nymphs developing on nectariless plants than on plants with nectaries. Apparently, the leaf nectaries are an important food source for the developing nymphs.

Pink bollworm.--'AET 5', a desirable upland breeding stock previously demonstrated as being resistant to the pink bollworm, has been combined with

other known resistance characters such as nectariless, smoothleaf, okraleaf, and early maturity. It compared favorably in yield with Deltapine and Stoneville varieties. The resistance mechanisms were identified in free-choice and no-choice tests as antixenosis and antibiosis.

Other pests.--Research on the development of varieties resistant to the cotton leafperforator and spider mites is in progress, and some success has been attained against spider mites.

Glandless cultivars.--Cotton cultivars that produce seed without gossypol are available and are grown in some areas. Cottonseed from these cottons can serve as a source of high protein food for humans and other nonruminants. Such cottons are more susceptible to assorted general feeding insects, but that disadvantage can be minimized if they are carefully scouted for insects and appropriate action is taken.

Biological Control

Predators, parasites, and diseases play an important role in the natural control of insect pests of cotton. Cotton-pest control programs should maximize the role of natural enemies by utilizing insecticides, cultural practices, and other agents and techniques in complementary ways. The key role of naturally occurring biological control agents must not be ignored in modern pest control programs. Wherever possible, an attempt should be made to evaluate the role of beneficial insects in the field. Some predaceous and parasitic insects of prime importance are discussed here.

Predators.--*Orius insidiosus* and *O. tristicolor* (Anthocoridae, Hemiptera), often called minute pirate bugs or flower bugs, are voracious predators of eggs and first-instar larvae of the bollworm, of thrips, and of other small insects. Populations often build up in such crops as corn and grain sorghum. Other Hemipterous insects, the big-eyed bugs, *Geocoris pallens*, *G. punctipes*, and *G. uliginosus*, are common predators of eggs and small larvae of the bollworm as well as other Lepidoptera, mirids, and aphids. Damsel bugs of the genus *Nabis* are efficient predators of a wide range of prey, including mirids, leafhoppers, aphids, and eggs and larvae of Lepidoptera. They attack bollworms as large as the second instar. Assassin bugs, particularly the genus *Zelus*, feed freely on eggs and larvae of Lepidoptera, including the bollworm, tobacco budworm, and cabbage looper. These bugs are usually less abundant in cottonfields than those referred to previously. *Podisus maculiventris* is a common stink bug that preys on large bollworms and other caterpillars.

Larvae of green lacewings, *Chrysopa* spp. (Chrysopidae, Neuroptera), are important predators of eggs and small larvae of the bollworm and other Lepidoptera and of many soft-bodied insects.

Ground beetles of the family Carabidae (Coleoptera) have considerable potential as predators in the cottonfield, but knowledge is lacking on the habits and factors affecting abundance of the many species. Lady beetles, (family Coccinellidae) are common predators in cottonfields. The larger species, including *Coleomegilla maculata*, *Hippodamia convergens*, and *Coccinella novemnotata*, feed on eggs and small larvae of the bollworm and other Lepidoptera and on aphids. Some smaller species in the genus *Scymnus* and all *Stethorus* spp. are primarily predators of mites. *Collops* beetles (Malachiinae in the family Melyridae) are often very abundant in cotton. They reportedly feed on the eggs and small larvae of the bollworm and other lepidopterous species.

Many families of Diptera contain species that are predaceous as adults or larvae. Best known as predators in cottonfields are the larvae of syrphid flies that prey primarily on aphids.

Family Formicidae (Hymenoptera) includes many predaceous species of ants. Iridomyrmex pruinosus is a regular predator of bollworm eggs. Other hymenopterous insects, the paper-nest wasps, Polistes spp., and solitary wasps of the genera Zethus, Eumenes, Rygchium, and Stenodynerus, provide their young in the nests with lepidopterous larvae. Wasps of the genus Sphex nest in the ground and provide their young with grasshoppers and related insects.

All spiders are predaceous, and many species are common in cottonfields. Orb weavers capture many moths in their webs. Wolf spiders and lynx spiders capture moths and other insects. Larvae and adults of the bollworm and boll weevil are among the prey of jumping spiders. Some species of thrips and mites are predators.

Judgments on predation are often difficult to make. The black fleahopper complex, Spanagonicus albofasciatus (Reuter) and Rhinacloa forticornis (Reuter), are predaceous but also feed on small squares. The cotton fleahopper, Pseudatomoscelis seriatus (Reuter) is better known as a pest from its feeding on terminal buds and small squares, but it is also a predator. The red imported fire ant, Solenopsis invicta Buren, is an effective cotton field predator, especially of the boll weevil, but it is a vexing nuisance of some medical importance. Phytophagous insects, such as thrips, aphids, fleahoppers, and leafhoppers, are pests at high populations but are important food for predators. Low-level populations should be tolerated or even encouraged.

Parasites.--Numerous species of hymenopterous parasites of several families are of great value in the biological control of many pests of cotton. These parasites vary tremendously in size, behavior, ecology, and host preference. Within their ranks, however, effective or potentially effective parasites in nearly every developmental stage (egg through adult) of the majority of cotton pests may be found. Many of them occur naturally in great numbers in certain geographical areas. Some are now, and many will eventually have to be, augmented in the field by habitat management or mass-release techniques so as to concentrate their populations at the time and in the place required for most effective control.

Flies of the family Tachinidae are parasites primarily of larvae of Lepidoptera and Coleoptera. Several species are of value as parasites of cotton pests and should be examined with the same goals in mind as those mentioned above; that is, augmentation through laboratory or field practices.

Highly effective technology for the mass-production and aerial release of the egg parasite Trichogramma spp. has been developed and extensively evaluated for use in managing Heliothis spp. in cotton. Although promising results were obtained in tests conducted in insecticide-free fields, the procedure apparently cannot be used effectively in areas where insecticides are used because of the extreme susceptibility of the parasites.

Native predators and parasites are often highly effective against bollworms, beet armyworms, tobacco budworms, cabbage loopers, cotton leafworms, cotton leafperforators, saltmarsh caterpillars, aphids, cutworms, lygus bugs, spider mites, whiteflies, and certain other pests. Diversified crops and uncultivated areas serve as refuge and reservoir areas for predators and parasites and, unfortunately, for some pests.

Although releases of large numbers of green lacewing larvae in field experiments in Texas controlled heavy infestations of bollworms, the method is not economically feasible with current technology. Releases of two species of

introduced parasites have shown promise for control of the pink bollworm, but more research is needed to develop such techniques into practical control measures. There are exotic species of predators and parasites of potential value in controlling both native and introduced cotton pests in the United States; however, research is needed to locate and introduce them and to evaluate their potential in pest control.

Diseases.--Naturally occurring outbreaks of polyhedral viruses sometimes substantially reduce bollworm, tobacco budworm, cabbage looper, and cotton leafworm populations. These viruses can be produced on hosts mass-reared on artificial diets. *Bacillus thuringiensis* is a naturally occurring insect pathogen that is produced commercially. Naturally occurring fungi often give control of spider mites and some species of insects. (See "Insecticides and Miticides Recommended for Cotton-Pest Control" for additional information on these diseases.) Such products have promise for use against low-density pest populations and/or in conjunction with other management techniques.

Chemical Defoliation and Desiccation

Chemical defoliation and desiccation of cotton aid in the control of many cotton insects. These practices check the growth of the plants and accelerate the opening of bolls, reducing the damage and the late-season buildup of boll weevils, bollworms, tobacco budworms, and pink bollworms that would otherwise remain to infest next year's crop. They also prevent or reduce damage to open cotton by heavy infestations of the cotton aphid, cotton leafworm, and whiteflies. However, defoliants and desiccants should not be applied until all bolls to be harvested are sufficiently developed to avoid losses in yield and quality. Stalks should be destroyed and other cultural practices followed. (See "Cultural Practices").

Guides for the different defoliants and desiccants are issued by the Cooperative Extension Services of the various States. They contain information concerning the influence of plant activity, stage of maturation, and effect of environment on the efficiency of the process and give details relating to the various needs and benefits. They explain how loss in yield and quality of products may be caused by improper timing of the applications. Local and State recommendations should be followed.

Production Mechanization in Insect Control

Increased mechanization improved the efficiency of cotton production and insect control. High-clearance sprayers and dusters and aircraft have proved very useful and satisfactory for the application of insecticides and defoliants, especially in rank cotton. Tractors also enable the grower to use shredders, strippers, mechanical harvesters, and larger, better plows--all of which help in the control of the pink bollworm and, to some extent, the boll weevil.

Mechanical harvesting with spindle pickers may result in leaving more infested cotton in the field than handpicking does, thus increasing the potential overwintering pink bollworm population. On the other hand, the use of strippers to harvest the crop is highly desirable from the standpoint of pink bollworm control, because all open bolls are stripped from the plants and are transported to the gin where a high percentage of the larvae are killed in the ginning process. Stalk shredders not only destroy certain insects, particularly the pink bollworm, but enable the cotton growers over wide areas to destroy the

stalks before frost and thereby stop the development of late generations of this insect and the boll weevil, bollworm, and tobacco budworm.

The increased use of mechanized equipment for cotton production has resulted in large acreages of uniform, even-aged stands in some areas. These factors tend to simplify cotton-insect control. Hibernation quarters in or immediately adjacent to the fields are frequently eliminated by these modern cultivation practices.

Insecticides and Miticides

Precautions

Hazards and precautions in the use of insecticides and miticides are discussed in this section. All chemical insecticides, of course, are toxic. On the other hand, when the enviable safety record associated with the use of many millions of pounds of insecticides on cotton annually is considered, it becomes evident that, if common sense precautions are observed, insecticides can be used with relative safety. This applies to the operator, farmworker, and cotton checker. These precautions will insure the safety of fish and wildlife, honey bees, our food and feed supply, and the public in general.

Problems involving exposure of man, domestic animals, crops, fish, beneficial insects, and wildlife to insecticides have been intensified by the use of insecticides for the control of cotton insects. The precautions, recommended amounts, and registration numbers are given on labels of all materials legally offered for sale. <u>These materials should not be used unless the user is prepared to follow directions on the labels.</u>

In handling any insecticides, avoid contact with the skin and the inhalation of dusts, mists, and vapors. Wear clean, dry clothing, and wash hands and face before eating or smoking. Launder clothing daily. Avoid spilling on the skin, and keep it out of the eyes, nose, and mouth. If any is spilled on the skin, wash it off immediately with soap and water. If you spill it on your clothing, remove the clothing immediately, and wash the contaminated skin thoroughly. Launder clothing before wearing it again. If the insecticide gets in the eyes, flush them with plenty of water for at least 5 minutes and get medical attention.

Insecticide injury to man may occur through skin absorption or by oral or respiratory intake. Some solvents used in preparing solutions or emulsions are flammable, and most of them are toxic to some degree. In considering the hazards to man, it is necessary to distinguish between immediate hazards (acute toxicity) and cumulative hazards (chronic toxicity).

Insecticides used on cotton, in all forms, must be handled with care at all times. The physiological activity of organophosphorus and carbamate compounds in both insects and warmblooded animals is primarily inhibition of the enzyme, cholinesterase. Initial or repeated exposure to them may reduce the cholinesterase level to the point where symptoms of poisoning may occur. These symptoms include headache, pinpoint pupils, blurred vision, weakness, nausea, abdominal cramps, diarrhea, and tightness in the chest. The symptoms may occur without forewarning. Applicators and handlers of these chemicals should be thoroughly aware of and familiar with the symptoms and the need to seek medical attention.

The toxicity of experimental compounds suggested for further testing may not be well known. Extreme precautions should be observed in their use until more information is available concerning their toxicity.

Formulations that have been accepted by the EPA under experimental permits are required to show prominently on the front panel of the label "For Experimental Use Only" and should be utilized only for such purposes.

The following insecticides can be used without special protective clothing or devices, although malathion may be absorbed through the skin and inhaled in harmful amounts. In all cases, follow the label precautions.

acephate
Bacillus thuringiensis
Baculovirus heliothis
dicofol
malathion
sulfur
trichlorfon

The following insecticides can be absorbed directly through the skin in harmful quantities. When working with these insecticides in any form, take extra care not to let them come in contact with the skin. Wear protective clothing and respiratory devices as directed on the label.

chlorpyrifos
diazinon
dimethoate
endosulfan
ethion
fenvalerate
methidathion
naled
permethrin
profenofos
propargite
sulprofos
toxaphene

The following chemicals are highly toxic and may be fatal if swallowed, inhaled, or absorbed through the skin. These highly toxic materials should be applied only by persons who are thoroughly familiar with their hazards and who will assume full responsibility for proper use of the chemicals and comply with all the precautions on the labels.

aldicarb
azinphosmethyl
carbophenothion
demeton
dicrotophos
disulfoton
endrin
EPN
methamidophos
methomyl
methyl parathion
monocrotophos
parathion
phorate
phosphamidon

Prevent skin absorption.--Many insecticides are almost as toxic when in contact with the skin as when taken orally. Such contact may occur through spillage or the deposition of fine mist or dust during application of insecticides. With the exception of aerosols, agricultural sprays and dusts have relatively large particles. When such particles are inhaled, they do not reach the lungs but are eventually brought into the throat and swallowed. Skin absorption constitutes a major route of entry, and yet it is the source of insecticide injury most likely to be ignored. Liquid concentrates are particularly hazardous. Load and mix them in the open. If you spill a concentrate on your skin or clothing, remove the contaminated clothing immediately, and wash the skin thoroughly with soap and water. Launder clothing before wearing it again. Contaminated shoes are a serious hazard. Launder work clothes, and change shoes daily. When recommended, wear natural or other suitable rubber

gloves while handling highly toxic compounds. Have a change of clothing and soap and water at hand in the field. Bathe at the end of the work period.

Prevent oral intake.--Keep food away from direct contact with all insecticides, and also keep it away from the possible fumigant action of volatile chemicals. Wash exposed portions of the body thoroughly before eating or drinking. Do not smoke or otherwise contaminate the mouth area before washing the face and hands. Do not measure or store pesticides in containers that might be mistaken for food containers. Store pesticides in the original containers only, with legible labels attached.

Prevent respiratory intake.--If called for on the label, wear a respirator or mask of a type that has been tested and found to be satisfactory for protection against the particular insecticide used. Decontaminate the respirator between operations by washing it and replacing the felts or cartridges or both at recommended intervals of use. Information on respirators certified for protection against insecticides may be obtained from the National Institute for Occupational Safety and Health, Testing and Certification Laboratory, 944 Chestnut Ridge Road, Morgantown, WV 26505.

Determine blood cholinesterase levels.--Regular users of organophosphorus compounds should have their blood cholinesterase levels checked before the start of a season's work and periodically thereafter. Atropine is used as a therapeutic agent for organophosphorus poisoning, but it must be administered under supervision of a physician; it is never used as a preventive agent. Another antidote for phosphorus poisoning is 2-PAM, which must be administered under the supervision of a physician. Be sure the local physician is familiar with the treatment and has the appropriate antidotes on hand before large-scale application has begun. Speed of proper treatment is essential. (See "Information on poison control centers" in this section.)

Most carbamates are also inhibitors of cholinesterase, and regular users of these chemicals should be checked and treated as above, with one exception: 2-PAM and other oximes are not recommended. These compounds are referred to as rapidly reversing inhibitors of cholinesterase. The reversal is so rapid that unless special precautions are taken the measurements of blood cholinesterase of humans or animals treated with these compounds are likely to be inaccurate and always in the direction of appearing to be normal. The blood cholinesterase inhibition should be measured by a technique that minimizes reactivation.

Dispose of excess materials and used containers.--Excess dusts or spray materials should be buried. The burial sites for excess insecticides, wastes, equipment washings, and containers should be selected with care and so situated that contamination of ground water does not occur. When possible, growers should carry their empty insecticide containers to a sanitary landfill dump and have them buried. Inform the dump operator of the nature of the residues in the containers. Some States require that they be buried at a designated place. Empty metal containers should be smashed beyond the possibility of reuse and buried.

Handle materials in the field carefully.--Metal containers of emulsifiable concentrates carried to the field should be placed in the shade. Agitation of closed containers left in the sun can result in pressure buildup in the container, with a resultant explosion of the contents when the top is removed.

Store insecticides properly.--Insecticides should be stored in a separate, fireproof building to avoid contamination of food, feedstuffs, or fertilizers. Care should be taken, also, to avoid cross-contamination of pesticides and herbicides. Unused insecticides should be kept in the original container and stored in places inaccessible to children, irresponsible persons, or animals. All insecticides should be stored under lock and key.

Procedures for applicators of insecticides.--Airplane pilots who are to apply insecticides should not assist in mixing or loading operations. Persons making ground application of organophosphorus insecticides or loading aircraft with them should always be accompanied by at least one other person in the field.

Information on poison control centers.--A publication entitled "Directory of Poison Control Centers" is available upon request from the Bureau of Chemical Hazards, Consumer Products Safety Commission, 5401 Westbard Avenue, Bethesda, MD 20016. It lists facilities in each state that provide to the medical profession, on a 24-hour basis, information concerning the prevention and treatment of accidents involving exposure to poisonous and potentially poisonous substances. The telephone directory may also list poison control centers for the local area.

Misapplication or drift of insecticides.--Spraying or dusting should be done under proper conditions and in such a manner as to avoid direct application or drift to adjacent fields where animals are pastured, to food or feed crops in the field, or to residential areas, canals, streams, waterways, or highways. Usually there is less drift from sprays than from dusts and from ground applications than from aerial applications. Injury from misapplication or drift is usually determined to be the responsibility of the applicator and farmer.

Residues in plants and soils.--In the development of new insecticides, the possibility of deleterious residues remaining in cottonseed and seed products must be thoroughly investigated. (See section entitled "Restrictions".)

Excessive insecticide residues in the soil may affect germination, rate of growth, and flavor of crops. Concentration of the residue is influenced by the insecticide, the formulation used, amount applied, type of soil, and climatic conditions. In the past, illegal residues were found in some root crops and in soybeans grown in rotation with cotton that had been treated with organochlorine insecticides.

Protect predators and parasites.--Predators and parasites play an important role in the control of cotton insects. Most currently available insecticides destroy these beneficial insects as well as harmful ones; therefore, the control program used should take maximum advantage of natural and cultural controls. Insecticides that are selective for the pest species concerned and of minimum detriment to the beneficial species should be used. When regular inspections show that high populations of predators and parasites are present, deferring of insecticide treatments should be considered.

Protect honey bees.--Every year pesticides applied to cotton cause extensive losses of honey bees. Much of this damage is needless and can be averted without reduced control of injurious pests if proper precautions are taken. Bees are beneficial to cotton, and many cotton growers as well as their neighbors grow legumes and other crops that require pollination. For the

benefit of the beekeeper, the cotton grower, and agriculture in general, every effort should be made to protect pollinating insects. Table 2 shows the relative toxicity to honey bees of insecticides used for the control of cotton insects.

Table 2.--Relative toxicity to honey bees of insecticides used for control of cotton insects

Group 1.--Materials highly toxic to bees exposed to direct treatment or residues	Group 2.--Materials toxic to bees when visiting field at time of application	Group 3.--Materials relatively low in toxicity to bees
acephate	carbophenothion	<u>Bacillus thuringiensis</u>
aldicarb	demeton	<u>Baculovirus heliothis</u>
azinphosmethyl	disulfoton	chlordimeform
carbaryl	endosulfan	dicofol
chlorpyrifos	endrin	diflubenzuron
diazinon	phorate	ethion
dicrotophos	----	propargite
dimethoate	----	sulfur
EPN	----	toxaphene
fenvalerate	----	trichlorfon
malathion	----	----
methamidophos	----	----
methidathion	----	----
methomyl	----	----
methyl parathion	----	----
monocrotophos	----	----
naled	----	----
parathion	----	----
permethrin	----	----
phosphamidon	----	----
profenofos	----	----
sulprofos	----	----

Bee losses can be reduced if the following general precautions are taken:

1. If a pesticide must be used, choose the one least hazardous to bees that will control the harmful pests.
2. If a hazardous material must be used, apply it when bees are not visiting the field.
3. Use sprays instead of dusts. Application with ground equipment is less hazardous to bees than application by airplane.
4. Avoid drift of pesticide into the apiary or onto adjacent crops in bloom.
5. Reduce the number of applications to an absolute minimum.
6. Advise the beekeeper to locate the apiary out of the usual drift path of the pesticide from the field.
7. Give the beekeeper advance notice if a hazardous material must be used, so he may move or otherwise protect the bees.

8. Remind the beekeeper that confining the bees during and after a single application may prevent or reduce damage and that colonies can be confined under wet burlap tarpaulins up to 2 days. Confinement is not practical if repeated applications are to be made.

Protect fish and wildlife.--Recommended precautions must be followed to reduce hazards to fish and wildlife when using insecticides for control of cotton insects. It is especially important to avoid direct application or drift to ponds, streams, standing water, and weedy areas. Wherever possible, cotton fields should be located away from ponds. Runoff from treated fields should be diverted from fish ponds. Where drift may create a problem, sprays are preferred to dusts, and ground applications are preferred to aerial applications. Do not discard pesticides or clean pesticide application equipment in or near streams or ponds.

Additional safeguards.--Equipment that has been used for mixing and applying 2,4-D and other weedkillers should never be used for mixing and applying insecticides to cotton because of the danger of crop injury resulting from contamination of the equipment.

Registration

Before a pesticide may be legally shipped in interstate or intrastate commerce, it must be registered under the Federal Insecticide, Fungicide, and Rodenticide Act as amended in 1978, which is administered by the Environmental Protection Agency (EPA). Scientific data are required to establish that the pesticide, when used as directed on the label, will control the target pest and will not cause unreasonable adverse effects to man and his surroundings. The criteria for registration are strict and subject to constant review as new information is developed. Many States have similar registration regulations. Under the new law, the Administrator of EPA is given the authority to proceed against persons or individuals who engage in misusing pesticides by applying them in a manner "inconsistent with their labeling." In addition, the Administrator may place pesticides in a "restricted use" category, thus subjecting them to controls in distribution and ultimately requiring their use only by certified applicators.

Cottonseed is classified as a food product. The undelinted seed as it comes from the gin is the "raw agricultural commodity." Where pesticide-use patterns will result in residues of the original material or of toxic metabolites on or in cottonseed or its byproducts, Maximum Residue Limits (MRL), or tolerances, must be established. The establishment of MRL tolerances in raw agricultural commodities is the responsibility of EPA. A registration will not be granted until an MRL of residue has been granted. Finite tolerances or exemption from tolerances are required for all pesticides registered for use on cotton.

Restrictions

Any regulations established by the Federal or State Governments will take precedence over those given in this report, which are as follows:

1. Workers entering cottonfields within 2 days after treatment with methyl parathion should wear clean, tightly woven protective clothing.
2. Do not repeat applications of dimethoate within 14 days of each other.

3. Do not apply disulfoton to cotton more than twice per season or repeat applications within 21 days of each other.

4. Do not repeat applications of monocrotophos within 5 days of each other.

5. Do not apply endosulfan, ethion, phorate, or propargite after bolls begin to open. Dosages of toxaphene in excess of 4 pounds per acre per application should not be applied to cotton after bolls open.

6. If cotton fields are to be grazed, observe grazing restrictions on the labels of all insecticides used on the crop.

7. Unused cottonseed intended for planting that has been treated with any insecticide should not be used for food or feed. Treated seed must bear a statement on the label indicating that the seed has been treated with the chemical and should be used for planting only.

The following insecticides have a field-reentry time after application of at least the interval indicated:

1 day--azinphosmethyl, chlordimeform, ethion, and phosphamidon
2 days--carbophenothion, demeton, dicrotophos, EPN, endrin, methomyl, methyl parathion, monocrotophos, oxydemeton-methyl, and parathion

The minimum number of days that should elapse between the time of the last insecticidal application and harvest for certain insecticides is as follows:

Hand harvest--
2 days--azinphosmethyl in ultra-low-volume applications
4 days--naled
5 days--endrin, methyl parathion
7 days--parathion
Hand or mechanical harvest--
1 day---azinphosmethyl
3 days--EPN
7 days--trichlorfon
14 days--diazinon, dimethoate, dicofol, chlorpyrifos, acephate, phosphamidon
15 days--methomyl
21 days--monocrotophos, demeton
28 days--disulfoton, phorate
30 days--dicrotophos
60 days--methidathion

The tolerances (parts per million) established for various insecticides recommended for cotton-insect control in or on cottonseed are as follows: acephate, 2.0; aldicarb, 0.1; azinphosmethyl, 0.5; carbaryl, 5; carbophenothion, 0.2; chlordimeform, 5; chlorpyrifos, 0.5; demeton, 0.75; diazinon, 0.2; dicofol, 0.1; dicrotophos, 0.05; diflubenzuron, 0.2; dimethoate, 0.1; disulfoton, 0.75; endosulfan, 1; endrin, 0; EPN, 0.5; ethion, 0.5; fenvalerate, 0.2; malathion, 2; methamidophos, 0.1; methidathion, 0.2; methomyl, 0.1; methyl parathion, 0.75; monocrotophos, 0.1; naled, 0.5; parathion, 0.75; permethrin, 0.5; phorate, 0.05; phosmet, 0.1; phosphamidon, 0.1; profenofos, 3; propargite, 0.1; sulprofos, 0.5; toxaphene, 5; and trichlorfon, 0.1. *Bacillus thuringiensis* and the nuclear polyhedrosis viruses are exempt from the requirements of a tolerance, and sulfur is a material not requiring a tolerance.

Some States have special restrictions on the use of certain insecticides. Check your State and local regulations.

Application

Formulations

Effective dust formulations of insecticides and miticides can be made, but these are not widely used in the protection of cotton from phytophagous pests. Most materials commonly used for control of cotton pests are formulated into sprays. Stable formulations of some materials are very difficult to make. Research on formulations continually provides more satisfactory material with greater stability.

Sprays.--The term "low volume" is used for the application of concentrated insecticides when the total volume of spray applied is more than one-half gallon but less than 10 gallons per acre. The term "ultra-low volume" is used for the application of concentrated or technical insecticides when the total volume of spray liquid applied is one-half gallon or less per acre.

Control of cotton insects and spider mites has been highly successful with properly formulated sprays applied at rates ranging from 1 quart to 15 gallons per acre. Most of the organic insecticide sprays used on cotton are made from emulsifiable concentrates. It is recommended that all insecticide formulators show conspicuously on the label the pounds of actual toxicant per gallon in emulsifiable concentrates. The pounds of toxicants specified should be consistent with the required label declaration of active ingredients. Occasional foliage injury has resulted from poorly formulated concentrates or when the spray was improperly applied. Emulsifiers and solvents should be tested for phytotoxicity before they are used in formulations. Phytotoxicity of emulsions may be aggravated by high temperatures, high concentrations, drying winds, and highly alkaline water. Diluted sprays should be applied immediately after mixing and should not be held for later use.

Ultra-low volume aerial applications of azinphosmethyl, endosulfan, malathion, and methyl parathion are approved for control of certain insects. A mixture of malathion plus methyl parathion is approved for boll weevil and bollworm control in the boll weevil infested States. Some progress has been made in applying other compounds in this manner and in developing ground equipment for their application. Results of limited research indicate that some emulsifiable materials perform differently when applied as ultra-low volume technical materials or as concentrates than when applied as emulsions. Because performance cannot be predicted, each insecticide applied in this manner must be tested thoroughly against various cotton pests. Hazards and residues from such applications must be considered. Expanded research is needed to develop this method of applying insecticides to control cotton insects.

Granules, fertilizer-insecticide mixtures, and seed treatments.--Systemic insecticides are sometimes applied as dusts or liquids to cottonseed before planting for early-season insect control. Such treatments sometimes adversely affect stands and seedling vigor. Granular or emulsifiable formulations of some systemic insecticides are applied in the seed furrow at planting for control of certain early-season insects. Granular formulations of some systemic insecticides are being used in some areas against certain foliage-feeding pests. Granular formulations of insecticides and mixtures of insecticides and fertilizers are used for control of some soil insects. They are being used for whitefringed beetle and wireworm control in some areas.

Mixtures of two or more insecticides.--When more than one insect or spider mite is involved in a control program, insecticides are frequently combined to give control of the species involved. Bollworm, cotton aphid, and spider mite buildup frequently follows application of some insecticides, and for this reason suitable insecticides or miticides are added to some formulations.

Where an outbreak of aphids or spider mites is involved, a recommended organophosphorus insecticide may be used alone or may be combined in a boll weevil-bollworm formulation.

Emulsifiable concentrates of two or more insecticides may be formulated into the recommended sprays in the field. When this is done, however, the quantity of solvent is increased, which may in turn increase the phytotoxicity hazard and toxicity to man and animals.

Mixtures containing less than recommended dosages of each of several insecticides have frequently been unsatisfactory and are not recommended.

Equipment

Insecticides may be applied to cotton with either ground or aerial equipment. Regardless of the equipment chosen, effective control is obtained only when applications give thorough coverage and are properly timed. Improperly timed or unnecessary applications may result in a pest complex that can cause greater damage to the cotton crop than the original target insect.

Ground application.--High-clearance rigs usually make efficient application possible in rank cotton with little mechanical injury to plants. Ground machines should be calibrated to apply the proper dosages for the speeds at which they will be operated.

Emulsifiable concentrates should be diluted immediately before use. Some type of agitation, generally the bypass flow, is necessary during the spray operation to insure a uniform mixture. As a safety measure, the spray boom should be located behind the operator.

Aerial application.--In aerial application of sprays with fixed-wing aircraft, booms and nozzles should be adjusted to give uniform coverage across the swath with the greatest possible concentrations of droplets in the desirable size range. Booms should not extend to the wing tips. The aircraft should be flown at a height of 5 feet above the crop for most effective insecticide placement and miminal drift. Fly-in clinics to assist aerial applicators in solving problems are proving to be effective and popular.

Emulsifiable concentrates should be mixed with water or vegetable oil immediately before use and delivered at 1 quart to 10 gallons per acre on a maximum swath width of 40 feet. Ultra-low volume concentrates should be applied at up to one-half gallon per acre on a swath width of 35 to 75 feet, depending on weather and other conditions. When insect populations are extremely heavy, it may be advantageous to narrow the swath width.

A method of flagging or marking the swaths should be used to insure proper distribution of both sprays and dusts.

Timing

Correct timing is essential for satisfactory control of cotton insects. Considerations must be given to the overall populations and stages of both beneficial and harmful insects rather than to those of a single insect. The stage of growth of the cotton plant and expected yield are important. Since the use

of insecticides often induces outbreaks of aphids, bollworms, spider mites, and other pests, insecticides should be applied only when and where needed.

Early-season applications should be made to control beet armyworms, cutworms, darkling ground beetles, grasshoppers, or other insects that threaten to reduce a stand. Recommendations for early-season applications to control aphids, plant bugs, boll weevils, cotton fleahoppers, and thrips vary greatly from State to State. Differences in the infestations of these insects, as well as in many other production factors, make it inadvisable to attempt to standardize recommendations for early-season control.

It is generally recommended that suitable insecticides be applied to cotton during its maximum period of fruiting and maturing if infestations threaten to reduce the yield, affect quality, or delay maturity. Recommendations for insecticide treatments are similar throughout the Cotton Belt, but certain details differ from State to State, and often within a State. The appropriate State "Guide for Controlling Cotton Insects" should be followed.

Effect on Cotton Plants

Many insecticides affect cotton plants physiologically, and certain solvents and additives may enhance the adverse effects of insecticides or may cause physiological effects of their own. The effects may result in delayed or advanced crop maturity with or without accompanying yield loss. Many organophosphorus compounds and the carbamate aldicarb used as seed or soil treatments have an effect on cotton plants expressed in more vigorous vegetative growth early in the season, resulting in taller plants and larger leaves, which can be related to physiological responses. Results have ranged from increased yield and early maturity to reductions in yield and delayed maturity at various locations in the Cotton Belt. The use of organophosphorus and carbamate insecticides at planting has often resulted in delayed plant emergence and poor stands.

Reductions in yield and delays in crop maturity have resulted when early-season foliar application schedules of several organophosphorus compounds have been used. However, more work has been done with methyl parathion, and its adverse effects are clearly documented under field conditions. The use of methyl parathion at rates greater than 0.5 pound per acre may result in reduced fruit retention. Though plants usually compensate for such fruit loss through production of added fruiting points, the result is delayed crop maturity and, in some cases, reduced yield. The most severe adverse effects of methyl parathion occur from frequent early-season applications. When methyl parathion is used only as needed, delayed maturity or yield loss is minimized. Results with carbaryl in California suggest similar reductions in fruit retention without compensating fruiting to offset fruit loss.

The effects of several insecticides on growth and fruiting of plants are inconsistent from one location to another and from year to year at any particular location. Adverse effects appear to be more common in some areas. Growers and insect control advisers should be aware of the potential adverse effects of insecticides on crop production. Insecticide use should be based on expected benefits from insect control weighed against possible losses in yield or delay in maturity if it is not used. Researchers should make a greater effort to distinguish between the growth and fruiting responses of plants to insecticides and those responses resulting from control of insects with them.

Recently, in the absence of insects, increases in yield have resulted from mid- and late-season applications of EPN plus methyl parathion, acephate, and chlordimeform.

Determining the Need for Chemical Control

The determination of pest population levels is fundamental in carrying out a sound cotton-insect control program. Entomologists recognize this basic principle and accept the professional obligation for implementing it. The need for control measures should be based on such factors as insect infestation counts, the value of the crop, and stage growth.

Insecticides or miticides are recommended for the control of injurious insect and spider mite pests of cotton when their populations reach the level at which economic losses will result if they are not controlled. This can result in the immediate loss of the fruiting forms (squares and bolls) or damage to the plant in such manner that fruiting will be delayed to the extent that a full crop cannot be made during the normal growing season. In areas subject to summer droughts or where the growing season is short, any insect injury causing damage to the extent that fruiting is delayed or early fruit is lost can result in reduced yields. The control of even a light infestation of injurious insects early in the season under these conditions may be important. In much of the Cotton Belt, however, the cotton plant usually is able to overcome early plant damage and early loss of fruit with little or no reduction in yield. In these areas, the need for protecting early fruit and for hastening maturity is minimized.

Some farmers have learned to recognize certain harmful and beneficial insects and certain insect diseases. They can determine by field inspections when an insecticide is needed, and by referring to the State Guide they can select the proper one to use. Other farmers prefer to employ persons who are specially trained to do the job for them. Many growers employ specially trained personnel, sometimes referred to as checkers or scouts, to make insect population counts and infestation records in cotton fields. The majority of the scouts are college students or former college students with some entomological background who have been given special training by the extension entomologist or by county agents. According to most farmers who have employed them, money spent for this purpose is a sound investment. The saving of one insecticide application during the year when infestation counts show that it is not needed, or the timely application of one that is needed, usually more than pays the entire cost of the service for the season.

Two uses of persons specially trained to make insect population counts and infestation records in cotton fields have developed. In one, the farmer hires the person to make the records and to submit them to him. The farmer then determines the need for insecticides, selects those to be used from the State Guide, and either applies them with his own equipment or arranges with a custom applicator to do it for him. In the other type of use, the farmer contracts with a consulting entomologist for the complete job of insect control. The consultant may have several individuals making population counts and infestation records for him. His experience enables him to use the records to determine the need for the insecticide. He makes the selection from the State Guide and either arranges directly for its application or leaves this to the discretion of the owner or manager, depending on the terms of the contract.

Both types of such trained persons have proved highly satisfactory to growers using them, and their use is increasing. With increased emphasis on reduction in cost of producing cotton and on decreased use of insecticides to avoid residues and other hazards, the precise knowledge of insect conditions and the wise use of insecticides are essential. The employment of trained persons usually is the best way to assure the job will be properly done.

Cotton-Pest Resistance to Insecticides and Miticides

Resistance to insecticides and miticides is the ability in insect and spider mite strains to withstand exposure to dosages that exceed those that normally control a susceptible population--such ability being inherited by subsequent generations of the strain. The resistance of cotton pests to insecticides has developed rapidly in recent years (table 3). Since 1947, when organic chemicals began to have wide usage in cotton, 25 species of insects and spider mites that attack the crop are known to have developed resistance, and several other species are strongly suspected of having developed resistance. One or more of these resistant species occur in localized areas in most cotton producing States from California to North Carolina. Most pest resistance has been to the organochlorine insecticides, but four species of mites and the beet armyworm, bandedwing whitefly, bollworm, and tobacco budworm are known to be resistant to some organophosphorus compounds. Observations of resistance to certain of the synthetic pyrethroids among populations of the tobacco budworm have been reported in the western regions of the Cotton Belt.

The resistance of cotton pests to recommended insecticides is a serious problem. It emphasizes the importance of using every known means possible to alleviate the difficulty to the extent that control may be maintained. This includes 1) implementation of effective pest management strategies which take full advantage of naturally-occurring beneficial species and cultural control practices, while carefully controlling insecticidal applications, to reduce the total pesticide burden, 2) the use of pesticides having different physiological modes of action from those to which resistance has been developed, and 3) changes in use patterns such as alternating use of different classes of insecticides. Every possible advantage of biological control agents should be utilized, and where there is a choice, chemicals that are of minimum detriment to beneficial insects should be used.

Effect of Environmental Factors on Chemical Control

Failures to control insects are often attributed to ineffective insecticides, poor formulations, poor applications, improper timing, and resistance to insecticides. Variations in humidity, rainfall, temperature, sunlight, and wind influence the effectiveness of an insecticide applied to plants. These variations also influence the development of insect populations and plant growth. The inability of the applicator to maintain a regular application schedule because of excessive rains or high winds often results in loss of control at a critical period.

Table 3.--Pests resistant to insecticides registered for use on cotton in one or more areas of various States

Pest	Insecticide	States
Bandedwing whitefly	Methyl parathion	Arkansas, Louisiana, Tennessee
Beet armyworm	Methyl parathion	Alabama, Arkansas
Boll weevil	Organochlorine compounds	Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas
Bollworm	Endrin	California
Do	Carbaryl	Arizona, Louisiana, Oklahoma, Texas
Do	Methyl parathion	Arkansas, Mississippi, Oklahoma
Do	Methomyl	Louisiana
Cabbage looper	Organochlorine compounds	Alabama, Arkansas, California, Louisiana, Mississippi, Oklahoma
Do	Endrin and toxaphene	Arizona
Do	Organophosphorus compounds	Arkansas, Louisiana, Mississippi
Cotton aphid	Methyl parathion	Mississippi
Cotton fleahopper	Organophosphorus compounds	Texas
Cotton leafperforator	Organochlorine compounds	California
Do	Organophosphorus compounds	California, Arizona
Cotton leafworm	Organochlorine compounds	Arkansas, Louisiana, Texas
Lygus hesperus	Trichlorfon and monocrotophos	California
Do	Malathion	Do
Saltmarsh caterpillar	Toxaphene and endrin	Arizona, Calfornia
Spider mites:		
Tetranychus turkestani	Organophosphorus compounds, except phorate seed or soil treatment	Alabama, California
T. cinnabarinus	Do	Alabama, Arizona, California, Texas
T. pacificus	Do	Do

Table 3.--Pests resistant to insecticides registered for use on cotton in one or more areas of various States--continued

Pest	Insecticide	States
T. urticae	Organophosphorus compounds, except phorate seed or soil treatment	Alabama, Arkansas, California, Louisiana, Mississippi, North Carolina
T. pacificus	Dicofol	California
T. urticae	Do	Do
Thrips:		
Frankliniella spp.	Endrin	California, New Mexico
Frankliniella occidentalis	Toxaphene	New Mexico
Tobacco budworm	Carbaryl	Alabama, Arizona, Arkansas, California, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Texas
Do	Endrin	Calfornia
Do	Methomyl	Arizona, Arkansas, Louisiana, Mississippi
Do	Organophosphorus compounds	Alabama, Arizona, Arkansas, California, Florida, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas
Do	Carbaryl	Florida

A combination of an adverse effect on the toxicity of the insecticide and a favorable effect on growth of the plant and insect population may result in failure to obtain control. Conversely, conditions favorable to the insecticide and plants and adverse to the insect population will result in very effective control. The use of fertilizer and supplemental irrigation, although valuable in cotton-production programs, may create conditions that make insect control difficult. Also certain insects, in particular the boll weevil, become more difficult to kill with some insecticides as the season progresses. Therefore, one should consider all factors before arriving at a decision as to the specific one responsible for the failure to obtain control.

Insecticides and Miticides Recommended for Cotton-Pest Control

Materials recommended for the control of pests in one or more states are discussed in this section (see table 4). In some areas certain pests have become resistant to one or more of the materials recommended. (See "Cotton-Pest Resistance to Insecticides" for details.) One asterisk (*) indicates an organochlorine compound; two asterisks indicate an organophosphorus compound.

**Acephate.--Acephate will control bollworms, tobacco budworms, cabbage loopers, cotton aphids, lygus bugs, thrips, spider mites, and whiteflies.

Aldicarb.--Aldicarb in granular form applied in the furrow at planting will control thrips, cotton aphids, cotton fleahoppers, leafminers, spider mites, lygus bugs, and overwintered boll weevils feeding on foliage. Sidedress applications when plants begin to square will control leafhoppers, cotton fleahoppers, boll weevils, spider mites, and lygus bugs but may result in an increase in subsequent bollworm and tobacco budworm infestations. Treatments at planting may result in phytotoxicity under some conditions to the extent that stands may be damaged. Stand reduction can be avoided by limiting in-furrow applications to no more than 1 pound of active ingredient per acre and using an "at plant" fungicide where seedling disease is prevalent. Aldicarb applied in-furrow at planting or as a sidedressing must be covered completely with soil. It is toxic to fish, wildlife, and birds. It should be kept out of any body of water, and care should be taken not to contaminate water when cleaning equipment or disposing of wastes. Birds and wildlife may be killed if allowed to feed on exposed granules. Aldicarb is highly toxic to man and animals and should be used with adequate precautions.

**Azinphosmethyl.--Azinphosmethyl will control cotton aphids, boll weevils, brown cotton leafworms, cotton leafperforators, cotton leafworms, fleahoppers, garden webworms, lygus bugs, pink bollworms, stink bugs, and thrips. Erratic results have been obtained against the cotton aphid and spider mite in some areas. It is ineffective against the beet armyworm and the saltmarsh caterpillar. Azinphosmethyl is highly toxic to man and animals and should be used with adequate precautions.

Bacillus thuringiensis.--*Bacillus thuringiensis* will control low to moderate infestions of the cabbage looper, the bollworm, and the tobacco budworm. It is used primarily in pest management programs.

Baculovirus heliothis.--*Baculovirus heliothis* will control low to moderate infestations of bollworms and tobacco budworms. It is used primarily in pest management programs.

Carbaryl.--Carbaryl will control boll weevils, bollworms, tobacco budworms, cotton fleahoppers, cotton leafworms, cotton leafperforators, cutworms, darkling beetles, fall armyworms, false celery leaftiers, field crickets, garden webworms, grasshoppers, leaf rollers (*Platynota stultana*), lygus bugs, pink bollworms, saltmarsh caterpillars, southern garden leafhoppers, stink bugs, and thrips. It does not control beet armyworms, black fleahoppers, cabbage loopers, false chinch bugs, or spider mites. Aphids do not usually build up following its use, but spider mites often do.

Table 4.--Common and chemical names of insecticides used for cotton-pest control

[*Indicates a proprietary name]

Common name	Chemical name	Other designation
acephate	O,S-dimethyl acetylphosphoramidothioate	*Ortho 12,420; *Orthene
aldicarb	2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl)oxime	UC 21149; *Temik
azinphosmethyl	O,O-dimethyl S-[(4-oxo-1,2,3-benzotriazin-3(4H)-yl)methyl] phosphorodithioate	*Guthion
carbaryl	1-naphthyl methylcarbamate	*Sevin
carbophenothion	S-[[(p-chlorophenyl)thio]methyl] O,O-diethyl phosphorodithioate	*Trithion
chlordimeform	N'-(4-chloro-o-tolyl)-N,N-dimethylformamidine	*Galecron; *Fundal
chlorpyrifos	O-O-diethyl O-(3,5,6-trichloro-2-pyridyl) phosphorothioate	*Lorsban
demeton	O,O-diethyl O-(and S)-[2-(ethylthio)ethyl] phosphorothioate	*Systox; mercaptophos
diazinon	O,O-diethyl O-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate	*Spectracide
dicofol	4,4'-dichloro-α-(trichloromethyl)benzhydrol	*Kelthane
dicrotophos	dimethyl phosphate ester of (E)-3-hydroxy-N,N-dimethylcrotonamide	*Bidrin
diflubenzuron	N-[[(4-chlorophenyl)amino]carbonyl]-2,6-difluorobenzamide	*Dimilin, TH6040
dimethoate	O,O-dimethyl S-(methylcarbamoylmethyl) phosphorodithioate	*Rogor; *Cygon; *Defend; *Rebelate
disulfoton	O,O-diethyl S-[2-(ethylthio)ethyl] phosphorodithioate	*Di-Syston; thiodemeton
endosulfan	6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin 3-oxide	*Thiodan
endrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-endo-5,8-dimethanonaphthalene	Compound 269
EPN	O-ethyl O-(p-nitrophenyl) phenylphosphonothioate	------------
ethion	O,O,O',O'-tetraethyl S,S,-methylene bis(phosphorodithioate)	*Nialate
fenamiphos	ethyl 4-(methylthio)-m-tolyl isopropylphosphoramidate	*Nemacur

Table 4.--Common and chemical names of insecticides used for cotton-pest control--Continued

[*Indicates a proprietary name]

Common name	Chemical name	Other designation
fenvalerate	cyano(3-phenoxyphenyl)methyl 4-chloro-α-(1-methylethyl) benzeneacetate	*Pydrin
flucythrinate	(±)-cyano(3-phenoxyphenyl) methyl (+)-4-(difluoromethoxy)-α-(1-methylethyl)benzeneacetate	*Pay-Off
malathion	O,O-dimethyl phosphorodithioate of diethyl mercaptosuccinate	*Cythion
methamidophos	O,S-dimethyl phosphoramidothioate	*Monitor
methidathion	O,O-dimethyl phosphorodithioate S-ester with 4-(mercaptomethyl)-2-methoxy-Δ^2-1,3,4-thiadiazolin-5-one	*Supracide; *Ultracide
methomyl	S-methyl N-[(methylcarbamoyl)oxy]thioacetimidate	*Lannate; *Nudrin
methyl parathion	O,O-dimethyl O-(p-nitrophenyl) phosphorothioate	*Metacide; *Wofatox
monocrotophos	dimethyl phosphate ester with (E)-3-hydroxy-N-methylcrotonamide	*Azodrin
naled	1,2-dibromo-2,2-dichloroethyl dimethyl phosphate	*Dibrom
oxydemeton-methyl	S-[2-(ethylsulfinyl)ethyl] O,O-dimethyl phosphorothioate	*Metasystox-R
parathion	O,O-diethyl O-(p-nitrophenyl) phosphorothioate	*Thiophos; *Niran
permethrin	(3-phenoxyphenyl)methyl 3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate	*Pounce; *Ambush
phorate	O,O-diethyl S-[(ethylthio)methyl] phosphorodithioate	*Thimet
phosphamidon	2-chloro-2-(diethylcarbamoyl)-1-methylvinyl dimethyl phosphate	*Dimecron
propargite	2-(p-tert-butylphenoxy)cyclohexyl 2-propynyl sulfite	*Comite; *Omite
profenofos	O-(4-bromo-2-chlorophenyl) O-ethyl S-propyl phosphorothioate	*Curacron
sulfur	sulfur	
sulprofos	O-ethyl O[4-methylthio)phenyl] S-propyl phosphorodithioate	*Bolstar
toxaphene	chlorinated camphene containing 67% to 69% chlorine	Camphechlor
trichlorfon	dimethyl (2,2,2-trichloro-1-hydroxyethyl)phosphonate	*Dipterex; *Dylox; *Proxol

**<u>Carbophenothion.</u>--Carbophenothion will control cotton aphids, cotton fleahoppers, cotton leafperforators, lygus bugs, thrips, and most species of spider mites. It appears to have long residual activity. It is not effective against the bollworm, boll weevil, or cabbage looper and is erratic against saltmarsh caterpillars and stink bugs. <u>Carbophenothion is highly toxic to man and animals and should be used with adequate precautions.</u>

<u>Chlordimeform.</u>--Chlordimeform will control beet armyworms, bollworms, tobacco budworms, cotton leafperforators, pink bollworms, spider mites, thrips, and western yellowstriped armyworms. Its action is primarily ovicidal, and it is presently labeled only as an ovicide for <u>Heliothis</u> spp. control.

**<u>Chlorpyrifos.</u>--Chlorpyrifos will control bollworms, boll weevils, cotton aphids, cotton fleahoppers, cutworms, fall armyworms, lygus bugs, pink bollworms, tobacco budworms, thrips, saltmarsh caterpillars, and spider mites.

**<u>Demeton.</u>--Demeton is both a contact and a systemic insecticide with long residual systemic activity. When applied as a foliage spray, it is effective against most species of aphids and spider mites for 2 to 8 weeks and controls the southern garden leafhopper and thrips. Demeton does not control boll weevils, bollworms, cotton leafworms, grasshoppers, or pink bollworms. <u>Demeton is highly toxic to man and animals and should be used with adequate precautions.</u>

**<u>Diazinon.</u>--Diazinon spray will control cotton fleahoppers, cotton leafperforators, lygus bugs, saltmarsh caterpillars, and thrips.

*<u>Dicofol.</u>--Dicofol is an acaricide with little insecticidal activity. It will control most species of spider mites. For best results spray should be applied at minimum of 20 gallons per acre with nozzles directed to give coverage under the leaf. Dicofol sprays from airplanes have given erratic results.

**<u>Dicrotophos.</u>--Dicrotophos spray will control cotton aphids, cotton fleahoppers, cotton leafperforators, false chinch bugs, lygus bugs, spider mites, saltmarsh caterpillars, stink bugs, and thrips. <u>Dicrotophos is highly toxic to man and animals and should be used with adequate precautions.</u>

<u>Diflubenzuron.</u>--Diflubenzuron will suppress low to moderate boll weevil populations by reducing the hatch of eggs from treated females. The toxicity of this compound is not fully known, but <u>extreme</u> caution should be observed in its use. (This compound was granted <u>conditional</u> registration by EPA in 1979.)

**<u>Dimethoate.</u>--Dimethoate spray will control cotton aphids, cotton fleahoppers, lygus bugs, and thrips.

**<u>Disulfoton.</u>--Disulfoton as a seed treatment or in granular or spray form applied in the furrow at planting will control aphids, leafminers, spider mites, and thrips for 4 to 6 weeks after planting. Treatments at planting may result in phytotoxicity under some conditions to the extent that stands may be damaged and early growth retarded. Phytotoxicity hazards may be greater where preemergence herbicides are used. Phytotoxicity hazards are also greater where certain fungicide combinations are used as planter box treatments with the seed. Planting seed should be treated only by custom operators who are able to treat

seed adequately and uniformly with suitable precautions against hazard to operators. Disulfoton is highly toxic to man and animals and should be used with adequate precautions.

*Endosulfan.--Endosulfan will control bollworms, tobacco budworms, cabbage loopers, cotton leafperforators, lygus bugs, stink bugs, and thrips.

*Endrin.--Endrin will control beet armyworms, boll weevils, bollworms, brown cotton leafworms, cabbage loopers, cotton leafperforators, cotton leafworms, cutworms, darkling ground beetles, fall armyworms, false chinch bugs, field crickets, flea beetles, fleahoppers, garden webworms, grasshoppers, greenhouse leaftiers, lygus bugs, stink bugs, tobacco budworms, thrips, and yellowstriped armyworms. Endrin used in a seed treatment will protect seed and young seedlings from seedcorn maggots, falsewireworms, and wireworms. It will not control the pink bollworm or spider mites. Aphids usually do not build up after applying endrin but spider mites sometimes do. Endrin should not be used for control of cotton insects where soybeans are grown in rotation with cotton. EPA has canceled registration for use of endrin on cotton in all areas east of Interstate Highway 35 and has listed restrictions for its use in areas west of Interstate Highway 35. Endrin is highly toxic to man and animals and should be used with adequate precautions. (Endrin is no longer included among insecticides recommended for use in controlling insect pests in the U.S.A.)

**EPN.--EPN will control boll weevils, bollworms, and tobacco budworms. EPN is highly toxic to man and animals and should be used with adequate precautions.

**Ethion.--Ethion will control cotton aphids, cotton leafworms, and most species of spider mites.

**Fenamiphos.--Fenamiphos applied in granular form in the furrow at planting will control thrips. Ordinary precautions are recommended for its use.

Fenvalerate.--Fenvalerate will control beet armyworms, bollworms, boll weevils, tobacco budworms, cotton leafperforators, thrips, whiteflies, and pink bollworms at 0.05 to 0.2 pound per acre and cabbage loopers and fall armyworms at 0.1 to 0.2 pound per acre. Spider mite infestations may develop following its use. Ordinary precautions are recommended in its use.

Flucythrinate.--Flucythrinate will control bollworms and tobacco budworms. Ordinary precautions are recommended in its use.

**Malathion.--Malathion spray will control boll weevils, cotton aphids, brown cotton leafworms, cotton leafperforators, cotton leafworms, fall armyworms, cotton fleahoppers, garden webworms, grasshoppers, lygus bugs, southern garden leafhoppers, thrips, and some species of spider mites. Results against whiteflies have been erratic. It will not control the bollworm or saltmarsh caterpillar. Malathion applied by airplane in ultra-low volume sprays at 0.5 to 1.25 pounds per acre controls the boll weevil.

**Methamidophos.--Methamidophos will control beet armyworms, boll weevils, bollworms, cabbage loopers, cotton aphids, cotton leafperforators, lygus bugs, saltmarsh caterpillars, spider mites, and thrips. Methamidophos is highly toxic to man and animals and should be used with adequate precautions.

**Methidathion.--Methidathion will control bandedwing whiteflies, spider mites, boll weevils, bollworms, lygus bugs, pink bollworms, and tobacco budworms. In a schedule of applications it may be phytotoxic.

Methomyl.--Methomyl will control beet armyworms, bollworms, tobacco budworms, cabbage loopers, cotton leafperforators, lygus bugs, and pink bollworms. It may be phytotoxic when repeated applications are used. A safened dust is less phytotoxic than sprays. Methomyl is highly toxic to man and animals and should be used with adequate precautions.

**Methyl parathion.--Methyl parathion will control beet armyworms, boll weevils, bollworms, cabbage loopers, cotton aphids, cotton leafperforators, cotton leafworms, cutworms, fall armyworms, false chinch bugs, fleahoppers, garden webworms, grasshoppers, lygus bugs, pink bollworms, southern garden leafhoppers, saltmarsh caterpillars, stink bugs, tobacco budworms, thrips, yellowstriped armyworms, and certain species of spider mites. Methyl parathion has a short residual toxicity. For late-season boll weevil control, a dosage of 0.25 pound at 3-day intervals is preferred over higher dosages at longer intervals. Although it is unsatisfactory for control of most species of spider mites, methyl parathion in a boll weevil schedule suppresses them. An encapsulated formulation of methyl parathion has shown promise against the boll weevil, bollworm, and cabbage looper at 0.5 to 1.0 pound per acre. Methyl parathion is highly toxic to man and animals and should be used with adequate precautions.

**Monocrotophos.--Monocrotophos will control bandedwing whiteflies, beet armyworms, boll weevils, bollworms, cabbage loopers, cotton aphids, cotton fleahoppers, cotton leafperforators, lygus bugs, pink bollworms, some species of spider mites, saltmarsh caterpillars, stink bugs, thrips, and tobacco budworms. This is a water-soluble compound, and observations indicate that it washes off more readily by rain than an emulsifiable concentrate does. Monocrotophos will kill birds and other wildlife. It should be kept out of any body of water and should be applied only when weather conditions favor drift from areas being treated. Monocrotophos is highly toxic to man and animals and should be used with adequate precautions.

**Naled.--Naled will control fleahoppers, cotton leafperforators, cutworms, grasshoppers, and lygus bugs.

**Oxydemeton-methyl.--Oxydemeton-methyl will control cotton aphids and most species of spider mites. This material is highly toxic to man and animals and should be used with adequate precautions.

**Parathion.--Parathion will control brown cotton leafworms, most species of aphids, cabbage loopers, cotton leafperforators, cotton leafworms, fleahoppers, lygus bugs, false chinch bugs, saltmarsh caterpillars, serpentine leafminers, southern garden leafhoppers, stink bugs, some species of spider mites, and thrips. At dosages of 0.5 to 1.0 pound per acre it controls the boll weevil, bollworm, and tobacco budworm. Parathion is highly toxic to man and animals and should be used with adequate precautions.

Permethrin.--Permethrin will control bandedwing whiteflies, boll weevils, bollworms, tobacco budworms, cotton leafperforators, lygus bugs, pink bollworms, and thrips at 0.05 to 0.2 pound per acre and cabbage loopers at 0.1 pound per acre. Spider mite infestations may develop following its use. Ordinary precautions are recommended in its use.

**Phorate.--Phorate as a seed treatment or applied in granular form in the furrow at planting will control aphids, leafminers, spider mites, and thrips for 4 to 6 weeks from planting date. Treatments at planting time may result in phytotoxicity under some conditions to the extent that stands may be damaged and early growth retarded. Phytotoxicity hazards may be greater where preemergence herbicides are used. Foliar applications of phorate will control spider mites. Phytotoxicity hazards are also greater where certain fungicide combinations are used as planter-box treatments with the seed. Planting seed should be treated only by custom operators who are able to treat seed adequately and uniformly with suitable precautions against hazard to operators. Phorate is highly toxic to man and animals and should be used with adequate precautions.

**Phosmet.--Phosmet will control boll weevils.

**Phosphamidon.--Phosphamidon will control cotton aphids, cotton fleahoppers, cotton leafperforators, false chinch bugs, lygus bugs and other mirids, and thrips. Phosphamidon is highly toxic to man and animals and should be used with adequate precautions.

**Profenofos. --Profenofos will control the bollworm-tobacco budworm complex. Profenofos is highly toxic to man and animals and should be used with adequate precautions.

Propargite.--Propargite will control the Pacific, strawberry, and twospotted spider mites.

Sulfur.--Sulfur has been widely used in dust mixtures for control of the cotton fleahopper and certain species of spider mites. When applied alone or in combination with insecticides in formulations containing 40 percent or more sulfur, it will control the desert and strawberry spider mites and will suppress other species. Precautions should be exercised in applying sulfur to cotton adjacent to cucurbits. The efficacy of certain insecticides formulated as emulsifiable concentrates may be reduced when tank-mixed with sulfur.

**Sulprofos.--Sulprofos will control the bollworm and tobacco budworm at 0.5 to 1.5 pounds and the beet armyworm and fall armyworm at 1.0 pound per acre. Sulprofos is highly toxic to man and animals and should be used with adequate precautions.

*Toxaphene.--On November 29, 1982, EPA cancelled the use of toxaphene on cotton except under emergency conditions with certain restrictions including a limitation on use to treatment of armyworms, cutworms, and grasshoppers; however, existing stocks registered for use on cotton may be purchased until December 31, 1983, and used according to the labeling on those products until December 31, 1986. Toxaphene will control beet armyworms, boll weevils, bollworms, cotton fleahoppers, cotton leafworms, cotton leafperforators, cutworms, fall armyworms, flea beetles, garden webworms, grasshoppers, lygus bugs, stink bugs, thrips, tobacco budworms, whitelined sphinxes, yellowstriped armyworms, and western yellowstriped armyworms. Toxaphene will not control cabbage loopers, pink bollworms, or saltmarsh caterpillars. (Toxaphene is no longer included among insecticides recommended for use in controlling insect pests in the U.S.A.)

**Trichlorfon.--Trichlorfon spray will control beet armyworms, celery leaftiers, cotton leafperforators, cutworms, darkling beetles, fall armyworms, field crickets, flea beetles, fleahoppers, garden webworms, leafrollers (Platynota stultana), lygus bugs, western yellowstriped armyworms, and yellowstriped armyworms. Trichlorfon has given erratic results against bollworms and cabbage loopers. It was effective against thrips at 0.5 to 1.0 pound per acre. Occasionally trichlorfon has been phytotoxic. It should be applied immediately after it is mixed with water.

Insecticides and Miticides Showing Promise in Field Tests

The materials listed and discussed in this section have shown promise in the testing programs of the State Agricultural Experiment Stations and the U.S. Department of Agriculture. These materials are not recommended for grower use but are recommended to research workers for further testing and study. One asterisk (*) indicates a proprietary name; two asterisks indicate an organophosphorus compound.

Tralomethrin (HAG-107 RU 25474) (1R1(S)3(RS)-2,2-dimethyl-3-(1,2,2,2-=tetrabromoethyl)-cyclopropanecarboxylate acid-cyano-3-(3-phenoxyphenyl)methyl ester

Field tests (1980-1983) of this compound have demonstrated activity against the boll weevil and Heliothis spp. (0.015-0.8 pounds per acre). Ordinary precautions are recommended in its use.

Avermectin-B_1a 2aE,4E,5'S,6S,6'R,7S,8E,11R,13R,15S,17aR,20R,20aR,20bS)-6'[(R)-sec-butyl]-7-[[2,6-dideoxy-4-O-(2,6-dideoxy-3-O-methyl-α-L-arabino-=hexopyranosyl)-3-O-methyl-α-L-arabino-hexopyranosyl]oxy]-5',6,6',7,10,11,14,15,17a,20,20a,20b-dodecahydro-20,20b-dihydroxy-5'6,8,19-tetramethylspiro[11,15-=methano-2H,13H,17H-furo[4,3,2-pq][2,6]benzodioxacyclooctadecin-13,2'-[2H]pyran]-17-one

Foliar applications of avermectin-B_1a in small plot tests have shown activity against the boll weevil. Results of laboratory tests suggest this chemical inhibits production of pheromone by adult male boll weevils.

BAY SIR 8514 (2-chloro-N-[[[4-(triflurometh oxy)phenyl]amino]carbomyl]=benzamide)

Field tests (1978-1983) have demonstrated that the reduction of boll weevil emergence from squares treated with this compound (0.0625 pound per acre) was comparable to that of diflubenzuron. This insect growth regulator has also shown activity against Heliothis spp. at a rate of 0.5 pound per acre. The toxicity of this compound is not fully known, but extreme caution should be observed in its use.

Cyfluthrin (*Baythroid, BAY FCR 1271) (cyano(4-fluoro-3-phenoxyphenyl)-=methyl-3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate)

Field tests (1980-1983) with this compound have indicated promise against the boll weevil, bollworm, tobacco budworm, aphids, whiteflies, (0.011125-0.02225 pound per acre), thrips (0.01 pound per acre), and tarnished plant bug (0.0005 pound per acre).

Ciba-Geigy (CGA-112913, AI3-29785) (N-[[[3,5-dichloro-4-[[3-chloro-5-=(trifluoromethyl)-2-pyridinyl]oxy]phenyl]amino]carbonyl]-2,6-difluorobenzamide)

This insect growth regulator has demonstrated activity (0.06-0.125 pound per acre) against the boll weevil and Heliothis spp.

Cypermethrin (*Ammo, *Cymbush) mixed isomers or (+)-[cyano(3-phenoxyphenyl)=methyl] cis, trans-(+)-3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate)

Field tests (1978-1983) with this compound have indicated promise against the boll weevil, bollworm, tobacco budworm, and Spodoptera spp. (0.03-0.12 pound per acre). Ordinary precautions are recommended in its use.

Fluvalinate (*Mavrik) (cyano(3-phenoxyphenyl)methyl-=2,2[[2-chloro-4-trifluoromethyl phenyl]amino-3-3 methylbutanoate])

Field tests (1979-1983) with this material demonstrated promise against boll weevils, bollworms, and tobacco budworms (0.05-0.2), and thrips (0.0125 pound per acre). Ordinary precautions are recommended in its use.

FMC 54800 (AI3-29675) ((2-methyl[1,1'-biphenyl-3-yl)methyl cis-3-(2-=chloro-3,3,3-trifluoro-1-propenyl)-2,2-dimethylcyclopropanecarboxylate)

Field tests of FMC 54800 in 1983 at rates of 0.04-0.06 pound per acre demonstrated promising activity against the boll weevil and Heliothis spp.

NRDC-161 (*Decis) ((S)-[cyano(3-phenoxyphenyl)methyl] cis (+)-3-(2,2-=dibromoethenyl)-2,2-dimethylcyclopropanecarboxylate)

Field tests of NRDC-161 in a spray have shown promise against the boll weevil, bollworm, tobacco budworm, pink bollworm, and cotton leafperforator at 0.01 to 0.02 pound per acre. The toxicity of this compound is not fully known, but extreme caution should be observed in its use.

**Stauffer SC-1069 (AI3-29814) (O-[1-(4-chlorophenyl)-1H-pyrazol-4-yl] O-ethyl S-propyl phosphorothioate)

Field tests of SC-1069 in 1983 at rates of 0.5-1.0 pound per acre demonstrated promising activity against Heliothis spp.

Thiodicarb (*Larvin) (dimethyl ester of N-N'(thiobis((methylimino)=carbonyl)oxy))bisethanimidothioc acid)

This material shows promise against the bollworm and tobacco budworm at 0.5-1.0 pound per acre, and against the beet armyworm, boll weevil, fall armyworm, and cabbage looper at 0.60-1.0 pound per acre. Laboratory tests indicated thiodicarb was less toxic to Trichogramma spp. than some other insecticides used on cotton. The toxicity of this material is not fully known but extreme caution should be observed in its use.

The following insecticides also indicated promise in field tests during 1983; chemical names were not available at the time this draft was prepared. Celamerk CME-13406 (active against Heliothis spp. at 0.03-0.12 pound per acre), Dupont DPX-H5249 (active against the boll weevil and Heliothis spp. at 0.25-0.5 pound per acre), Nor-Am SN-89462 (active against Heliothis spp. at 0.5 pound per acre), and Velsicol CN-11-3859 (active against Heliothis spp. at 0.05-0.1 pound per acre.

COTTON INSECTS AND SPIDER MITES AND THEIR CONTROL

The insects and spider mites injurious to cotton and the recommended chemicals and procedures for their control are discussed in this section.

Dosage ranges for insecticides recommended in one or more States for the control of cotton pests are also discussed. In local areas certain insects have become resistant to one or more of the insecticides recommended for general use; see "Cotton-Pest Resistance to Insecticides and Miticides" for details.

Beet Armyworm, *Spodoptera exigua* (Hübner)

The following insecticides will control the beet armyworm in some areas at the indicated dosages of technical material:

Spray	Pounds (AI) per acre
Acephate	0.25-1.0
Chloropyrifos	0.75-1.0
Methidathion	0.25-0.5
Methamidophos	0.5-1.0
Methomyl	0.45-0.67
Methyl parathion	1.00-1.5
Monocrotophos	0.25-1.0
Profenofos	0.75-1.0
Sulprofos	0.75-1.5
Trichlorfon	1.00

Corn meal and citrus pulp baits containing 1.25 or 2.5 percent methomyl applied at 20 pounds per acre have shown promise against the beet armyworm and bollworm. The beet armyworm often is a pest of seedling cotton, but it also attacks older plants. Squares and blooms may be destroyed, and feeding on the bracts may cause small bolls to shed. The beet armyworm has been a pest in the West and Southwest for many years. In the Mid-South and Southeast its occurrence in numbers is sporadic, but severe local outbreaks are not uncommon.

Boll Weevil, *Anthonomus grandis* Boheman

The boll weevil has been reported in all the States included in the Cotton Belt of the USA. Since 1960 it has extended its range to west Texas and is now found in parts of Arizona, California, and New Mexico.

The effectiveness of insecticides approved for boll weevil control will vary not only in different localities but also in the particular area where the insect is to be controlled. Dosages of technical material that have controlled the boll weevil in mid- and late-season in one or more areas are as follows (dosages lower than these are used for early-season control in some areas):

Spray	Pounds (AI) per acre
Azinphosmethyl[1/]	0.125-0.5
Carbaryl	0.8-2.0
Chlorpyrifos	0.75-1.0
EPN	0.25-0.5
EPN + methyl parathion	0.25-0.5+0.25-0.5
EPN + methyl parathion + chlorpyrifos	1.0+1.0+0.5
Fenvalerate	0.1-0.2
Malathion[1/]	0.5-1.2
Methomyl	0.125-0.25
Methomyl + methyl parathion	0.22+0.5
Methyl parathion[1/]	0.25-2.0
Monocrotophos	0.6-1.0
Parathion	0.25-1.0
Permethrin	0.1-0.2

[1/] Azinphosmethyl, malathion, and methyl parathion may be applied ultra-low volume as technical material at 0.125 to 0.25 pound, 0.5 to 1.2 pounds, and 0.5 to 0.75 pound per acre, respectively.

When these insecticides are used for boll weevil control, other insect problems have to be considered. Infestations of cotton aphids, bollworms, spider mites, and tobacco budworms may develop when some of these insecticides are used alone. Spider mites may build up rapidly after the use of toxaphene or carbaryl. Careful checks should be made at 5- to 7-day intervals. If these pests are found to be increasing, control measures should be started at once. (See "Cotton Aphid, *Aphis gossypii* Glover" and "Spider Mites" in this section.)

Aldicarb is effective against overwintered boll weevils when used as an in-furrow granule application at planting at 0.6 to 1.0 pound (0.3 to 0.5 pound if hill-dropped) per acre.

Diflubenzuron will suppress low populations of the boll weevil at 0.06 pound per acre; it is particularly effective in preventing the hatch of eggs from overwintering females. Egg hatch from treated females may resume within 7 days after treatments are discontinued, thus a clean-up application of an organophosphorus insecticide might be needed at that time. However, there is a risk in implementing the latter treatment because it might deplete populations of beneficial species at a time when there is a potential for outbreaks of *Heliothis* spp.

Boll weevil control measures should be taken when definite need is established. Experience indicates that mid- and late-season control programs may require frequent applications. Fields should be inspected weekly until bolls are no longer susceptible to attack by weevils. Where early-season control is required, experience indicates that frequent treatments may also be needed during the period of abundance of overwintered weevils. Insecticide treatments should be based on actual need.

Certain chemical and cultural control procedures may be used during and immediately following cotton harvest to greatly reduce the overwintering boll weevil population. The boll weevil survives the winter as a diapausing adult. Most of the adults must feed on fruiting forms for approximately 10 days to 3 weeks to attain diapause. Very few weevils attain diapause when insecticides are applied for their control before cotton matures. Large numbers of weevils attain diapause soon after the termination of the regular control program and before the food supply is destroyed, either by a killing frost or by chemical and mechanical methods. A proper combination of practices at this time, including applications of organophosphorus insecticides, defoliation, and stalk destruction to prevent the development of diapause by the weevils, will reduce overwintering populations by approximately 90 percent.

Bollworm, *Heliothis zea* (Boddie), and Tobacco Budworm, *H. virescens* (F.)

The bollworm and the tobacco budworm are the most common lepidopterous species that attack cotton. Several other species that cause boll injury, discussed elsewhere in this report, are the beet armyworm, fall armyworm, pink bollworm, yellowstriped armyworm, and western yellowstriped armyworm.

The bollworm and tobacco budworm occur throughout the Cotton Belt. Effective control of these species depends on the thoroughness and proper timing of insecticide applications. Frequent field inspections to determine the presence of eggs, young larvae, and square damage during the fruiting period are essential. For the most effective control, it is essential that insecticide applications be made when larvae are small.

Dosages of technical material that have controlled bollworms in one or more areas are as follows:

Spray	Pounds (AI) per acre
Acephate	0.75-1.0
Bacillus thuringiensis	0.25-0.5
Baculovirus heliothis	0.12-0.25
Carbaryl	1.0-2.0
Chlordimeform	0.12-0.25
Chlordimeform + fenvalerate	0.125+0.1
Chlorpyrifos	1.0
Chlorpyrifos + sulprofos	0.25-0.5+0.5-1.0
EPN	0.75-1.0
EPN + methyl parathion	0.25-1.0+0.5-1.0
EPN + methyl parathion + chlordimeform	0.5-1.0+0.4-1.0+0.125-0.25
EPN + methyl parathion + chlorpyrifos	0.5+0.5+0.5
EPN + methyl parathion + methomyl	0.5+0.5+0.125-0.33
Fenvalerate	0.1-0.2
Fenvalerate + chlordimeform	0.1 + 0.125
Fenvalerate + chlorpyrifos	0.05-0.1+0.5-1.0
Flucythrinate	0.025-0.08
Methomyl[1/]	0.45-0.67
Methyl parathion[2/]	1.0-2.0
Methyl parathion + methomyl	0.5-1.0+0.25
Monocrotophos	0.6-1.0
Parathion	1.0
Permethrin	0.1-0.2
Permethrin + chlordimeform	0.1+0.125
Permethrin + chlorpyrifos	0.05-1.0+0.5-1.0
Profenofos	0.5-1.0
Sulprofos	0.5-1.5
Methomyl + fenvalerate	0.125+0.1
Methomyl + permethrin	0.125+0.1

[1/]Methomyl may be applied at 0.12-0.25 pound per acre as an ovicide.
[2/]May be applied ultra-low volume at 0.5 to 0.75 pound per acre.

Cabbage Looper, *Trichoplusia ni* (Hübner)

The following materials applied at 5-day intervals have given control of the cabbage looper and related species in one or more areas:

Spray	Pounds (AI) per acre
Acephate	0.75-1.00
Bacillus thuringiensis	0.25-1.0
Fenvalerate	0.1-0.2
Methamidophos	0.5-1.0
Methomyl	0.45
Monocrotophos	0.6-1.0
Permethrin	0.1-0.2

The cabbage looper is frequently controlled naturally by viruses and fungi. When diseased loopers are commonly found, chemical control may be delayed or omitted.

Cotton Aphid, *Aphis gossypii* Glover

Heavy infestations of the cotton aphid may occur on cotton after the use of certain insecticides and on seedling cotton and sometimes on older cotton where no insecticides were applied. When aphid infestations are heavy and rapid kill is needed, any one of the following treatments is usually effective at the following dosages of technical material:

Spray	Pounds (AI) per acre
Azinphosmethyl	0.25
Carbophenothion	0.5-1.0
Chlorpyrifos	0.25-0.5
Demeton	0.125-0.38
Dicrotophos	0.1-0.375
Dimethoate	0.1-0.25
Endosulfan	0.6-1.0
Ethion	0.5
Malathion	0.5-1.25
Methamidophos	0.5-1.0
Methyl parathion	0.25-0.5
Monocrotophos	0.3
Oxydemeton-methyl	0.25-0.37
Parathion	0.1-0.5

The following materials are effective when used as seed treatments or as in-furrow granule applications at planting at the indicated dosages of technical material:

Insecticide	Pounds (AI) per acre
Aldicarb	0.3-0.5
Disulfoton	0.5-1.5
Phorate	0.5-1.5

Cotton Fleahopper, *Pseudatomoscelis seriatus* (Reuter)

The cotton fleahopper frequently attacks cotton in Texas and Oklahoma and, to a lesser extent, in other areas. It can be controlled with the following insecticides at the indicated dosages of technical material:

Spray	Pounds (AI) per acre
Acephate	0.1-0.2
Azinphosmethyl	0.1-0.25
Carbaryl	0.25-1.40
Chlorpyrifos	0.175-1.0
Dicrotophos	0.1-0.25
Dimethoate	0.1-0.25
Malathion	0.7-1.25
Methyl parathion	0.12-0.5
Trichlorfon	0.25-1.0

Aldicarb is effective when used as an in-furrow granule application at planting at 0.6 to 1.0 (0.3 to 0.5 if drill dropped) pound per acre.

The whitemarked fleahopper, *Spanagonicus albofasciatus* (Reuter), and the western plant bug, *Rhinacloa forticornis* (Reuter), occur on cotton in the irrigated west. The former species also occurs in the Mississippi Delta and in Texas. More information is needed on both of these species to clarify their roles as economic pests of cotton and as predators.

Cotton Leafperforator, *Bucculatrix thurberiella* Busck

The cotton leafperforator is at times a serious defoliator of cotton in certain areas of southern California and Arizona. It is controlled with methomyl (spray or dust) at 0.45 to 0.67 pound per acre (technical material). Repeat applications may be necessary. Sprays are more effective than dusts. Avoid the use of organophosphorus compounds during early season to protect beneficial insects. Aldicarb is effective when applied as a sidedressing between first squaring and early bloom at 2.0 pounds per acre. Chlorpyrifos at a rate of 1.0 pound per acre will aid in suppressing this pest.

Cotton Leafworm, *Alabama argillacea* (Hübner)

The following insecticides will control the cotton leafworm at the indicated dosages of technical material:

Spray	Pounds (AI) per acre
Azinphosmethyl	0.25-0.37
Carbaryl	0.5-2.0
EPN + methyl parathion	0.25-0.5+0.25-0.5
Malathion	0.4-1.25
Methyl parathion	0.25-0.5
Parathion	0.12-0.25

Cutworms

Several species of cutworms, including the following, may develop in weeds or crops, especially legumes, and then attack adjacent cotton or cotton planted on land previously in weeds or legumes:

Black cutworm, *Agrotis ipsilon* (Hufnagel)
Palesided cutworm, *A. malefida* Guenée
Variegated cutworm, *Peridroma saucia* (Hübner)
Granulate cutworm, *Feltia subterranea* (F.)
Army cutworm, *Euxoa auxiliaris* (Grote)

Recommended control measures include thorough seedbed preparation, elimination of weed host plants, and the use of insecticides. In western areas, irrigation forces the subterranean forms to the surface where they may be treated with insecticides or destroyed by natural factors. If the vegetation in an infested area is destroyed by tillage 3-6 weeks before the cotton crop is seeded, an insecticide may not be needed. The following insecticides will control one or more species of cutworms at the indicated dosages of technical material:

Spray	Pounds (AI) per acre
Acephate	1.0
Carbaryl	1.5-2.0
Chlorpyrifos	0.75-1.0
Sulprofos	0.75-1.5
Trichlorfon	0.5-1.5

Baits containing carbaryl at 1.5 pounds per acre, and trichlorfon at 1.5 pounds per acre have been satisfactory. Baits are frequently more effective than sprays or dusts against some species of cutworms.

Darkling Ground Beetles, Blapstinus spp. and Ulus spp.

Darkling ground beetles, the adults of false wireworms, occasionally affect the stand of young cotton in the western areas. Adults on young plants may be controlled with carbaryl in a bait at 1.5 pounds per acre.

Fall Armyworm, Spodoptera frugiperda (J. E. Smith)

The fall armyworm occasionally occurs in sufficient numbers to damage cotton. The following insecticides will control it at the indicated dosages of technical material:

Spray	Pounds (AI) per acre
Acephate	1.0
Carbaryl	1.0-2.0
Chlorpyrifos	0.25-0.5
EPN + methyl parathion + chlorpyrifos	0.5+0.5+0.5
EPN + methyl parathion + methomyl	0.5+0.5+0.25-0.33
Methomyl	0.3-0.67
Methyl parathion	0.25-1.50
Monocrotophos	0.5-1.0
Sulprofos	0.75-1.5
Trichlorfon	0.5-1.0

The results obtained from these materials have varied in different states; therefore, local recommendations should be followed. (See "Bollworm, Heliothis zea (Boddie), and Tobacco Budworm, H. virescens (F.)" in this section.)

Garden Webworm, Achyra rantalis (Guenée)

The garden webworm may be controlled with the following insecticides at the dosages indicated:

Spray	Pounds (AI) per acre
Carbaryl	1.0-2.0
Malathion	1.0-2.0
Methyl parathion	0.25-0.5

Grasshoppers

Several species of grasshoppers, including the following, sometimes attack cotton:

American grasshopper, Schistocerca americana (Drury)
Trimerotropis pallidipennis pallidipennis (Burmeister)
Differential grasshopper, Melanoplus differentialis (Thomas)
Lubber grasshopper, Brachystola magna (Girard)
Migratory grasshopper, M. sanguinipes (F.)
Redlegged grasshopper, M. femurrubrum (De Geer)
Twostriped grasshopper, M. bivittatus (Say)

The American grasshopper overwinters as an adult and in the spring deposits eggs in the fields. Other species of grasshoppers overwinter as eggs in untilled soil, fence rows, sod waterways, around stumps, and similar locations. The species overwintering in the egg stage can be controlled best with early treatment of hatching beds before the grasshoppers migrate into the fields. Sprays or dusts have largely replaced poison baits, particularly where grasshoppers must be controlled on lush or dense vegetation. Dosages of technical material suggested to control grasshoppers on cotton come within the following ranges:

Spray	Pounds (AI) per acre
Carbaryl	1.0-2.0
Chlorpyrifos	0.25-0.5
Malathion	1.0-2.0
Methyl parathion	0.25-0.5

The lowest dosages are effective against newly hatched to half-grown grasshoppers. The dosages should be increased as the grasshoppers mature or when the material is applied on partly defoliated plants or on plants unpalatable to the insects.

Lygus Bugs and Other Mirids

Several species of lygus bugs and other mirids, including those listed below, often are serious pests of cotton. (See "Cotton Fleahopper, Pseudatomoscelis seriatus (Reuter)" in this section.)

A plant bug, Lygus hesperus Knight
Clouded plant bug, Neurocolpus nubilus (Say)
Ragweed plant bug, Chlamydatus associatus (Uhler)
Rapid plant bug, Adelphocoris rapidus (Say)
Superb plant bug, A. superbus (Uhler)
Tarnished plant bug, Lygus lineolaris (Palisot de Beauvois)

The mirids Creontiades debilis Van Duzee, Reuteroscopus ornatus (Reuter), R. sulphureus (Reuter), and Paraxentus guttulatus (Uhler) also damage cotton. Creontiades rubrinervis (Stål) has been reported in cotton in the lower Rio Grande Valley of Texas. These insects cause damage to squares, blooms, and small bolls of cotton and constitute a major problem, particularly in the

vicinity of alfalfa fields in the irrigated areas of the West. The following insecticides will control lygus bugs and other mirids at the indicated dosages of technical material:

Spray	Pounds (AI) per acre
Acephate	0.12-1.0
Azinphosmethyl	0.125-0.25
Carbaryl	0.6-2.0
Chlorpyrifos	0.175-1.0
Dicrotophos	0.1-0.5
Dimethoate	0.1-0.25
Malathion	0.7-1.25
Methyl parathion	0.12-1.0
Monocrotophos	0.1-0.5
Trichlorfon	0.25-1.5

Aldicarb is effective when used as an in-furrow granule application at planting at 0.6 to 1 pound per acre.

Pink Bollworm, *Pectinophora gossypiella* (Saunders)

The pink bollworm occurs on the North American continent in Texas, California, Nevada, Oklahoma, New Mexico, Arizona, Arkansas, and Louisiana. It occurs in wild cotton in southern Florida. Although it also occurs in most of Mexico, it was found for the first time in 1965 in limited areas of the previously uninfested states of Sonora and Baja California. Quarantine regulations, the application of chemical controls, and cultural control requirements have made it possible to prevent economic damage in most years in the infested areas of the United States and to retard or prevent its spread to new areas. However, in recent years injurious infestations have occurred in the Imperial, Palo Verde, and Coachella Valleys of California and in Arizona.

Quarantine requirements.--The areas presently under regulation in the United States are shown in figure 1. The regulations, in general, require that all cotton or other designated articles moved from the regulated areas be treated to free them of any living pink bollworms before movement to free areas. All cottonseed must be treated before being shipped from a regulated area. Copies of the State and Federal regulations may be obtained from the regulatory agencies of the affected States or from the Plant Protection and Quarantine Programs field office.

Cultural Control.--Approved cultural practices, effective and economical means of controlling the pink bollworm when properly carried out, greatly reduce the overwintering population. The pink bollworm hibernates in waste cotton left in the field, along roadsides, and at the gin; therefore, destruction of this material aids considerably in the control of this pest. Mandatory cultural control zones are in effect in the United States in the southern, central, and eastern sections of Texas and in regulated areas of Arkansas, Louisiana, Arizona, and California. Cultural practices used in pink bollworm control are effective in reducing the boll weevil carryover for the next year. Recommended control practices include the following:

1. Shorten the planting period and plant at the optimum time for a given locality. Use seeds of an early-maturing variety that have been culled, treated with a fungicide, and tested for germination.

2. Leave as thick a stand as has been recommended for the particular area and type of soil.

3. Produce the cotton in the shortest practicable time. Early-season control of certain insects has proved advantageous in some States but not in others. Practice early-season control where recommended by controlling cotton aphids, boll weevils, cotton fleahoppers, cutworms, thrips, and any other insects that may retard the growth and fruiting of young plants. Protection of early fruit will assure an early harvest.

4. Withhold late irrigation, and use defoliants or dessicants to hasten the opening of the bolls when the crop is mature.

5. Harvest cleanly; in areas where spindle pickers are used, final scrapping with a stripper is desirable. Use a cotton gleaner if appreciable cotton is left on the ground after harvest.

6. Shred and plow under cotton stalks and debris as soon as possible after harvest. Okra stalks and debris should be shredded and plowed under at the same time because this plant is a preferred secondary host.

7. In cold areas where winter irrigation is not feasible, leave stalks standing until lowest temperatures have occurred. This is to secure a maximum kill of pink bollworms in the bolls on the stalks. However, if a large amount of crop debris, such as seed cotton or locks, is on the soil surface, a high survival of the pest may result. When this condition exists, the stalks should be shredded and plowed under as early and as deeply as possible.

8. In warmer areas the growing of volunteer and stub cotton should not be practiced.

The flail shredder is recommended over the horizontal rotary shredder for pink bollworm control. The flail shredder will kill about 85 percent of the pink bollworms left in the field after harvest, compared to 55 percent for the horizontal rotary shredder. The residue should be plowed under as deep as possible. Pink bollworm winter survival is highest in bolls on the soil surface and is six times as high in bolls buried only 2 inches deep as compared with bolls buried 6 inches deep. Before fruiting, all sprout and seedling cotton and okra developing after plowing should be destroyed to create a host-free period between crops. In arid areas, if the crop debris is plowed under in the late fall or early winter, the fields should be winter-irrigated to increase pink bollworm mortality.

Control with insecticides.--Where infestations are heavy, crop losses from pink bollworms can be reduced by proper use of insecticides.

Spray	Pounds (AI) per acre
Azinphosmethyl	0.5-1.0
Carbaryl	1.5-2.5
Chlorpyrifos	1.0
Fenvalerate	0.05-0.1
Monocrotophos	0.6-1.0
Permethrin	0.1-0.2

Saltmarsh Caterpillar and Other Arctiids

The saltmarsh caterpillar, Estigmene acrea (Drury), is a late-season pest of cotton principally in western irrigated areas. It may be controlled with the following insecticides at the indicated dosages of technical material:

Spray	Pounds (AI) per acre
Carbaryl	2.0
Chlorpyrifos	0.5-1.0
Methyl parathion	1.0
Trichlorfon	1.5

Occasionally, the yellow woollybear, Diacrisia virginica (F.), and the hairy larvae of several other tiger moths (Arctiidae), including Callarctia phyllira (Drury), C. arge (Drury), and C. oithona Strk., cause serious damage to cotton. Information is needed on their seasonal host plants, distribution, natural enemies, causes of serious outbreaks in cottonfields, life history, and control. (Determinations of species by specialists should always be obtained.)

Spider Mites

The following spider mites are known to attack cotton:

Carmine spider mite, Tetranychus cinnabarinus (Boisduval)
Desert spider mite, T. desertorum Banks
Fourspotted spider mite, T. canadensis McGregor
Pacific spider mite, T. pacificus McGregor
Schoene spider mite, T. schoenei McGregor
Strawberry spider mite, T. turkestani Ugarov and Nikolski
Tumid spider mite, T. tumidus Banks
Twospotted spider mite, T. urticae Koch and T. ludeni Zacker
T. yustis McGregor

The species differ in their effect on the cotton plant and in their reaction to miticides. Accurate identification of the species is essential. The use of organic insecticides for cotton-insect control has been a factor in increasing the importance of spider mites as pests of cotton. Table 5 lists the species of spider mites and the miticides that have been found to be effective in their control. For the control of some species and suppression of others, at least 40 percent sulfur may be incorporated in dusts. Elemental sulfur cannot be incorporated in sprays applied at low gallonage, but other miticides may be substituted. Sulfur dust is more effective when finely ground and when applied at temperatures above 90°F; thorough coverage is essential. Some difficulty in the control of spider mites has been experienced with ultra-low volume applications of recommended miticides, probably because of insufficient plant coverage.

Stink Bugs

The following bugs are sometimes serious pests of cotton:

Brown stink bug, Euschistus servus (Say)
Conchuela, Chlorochroa ligata (Say)
Dusky stink bug, E. tristigmus (Say) and E. conspersus (Uhler)

Table 5.--Recommended dosages of miticides for control of specific species of spider mites

[Pounds (AI) per acre]

Miticide	Species								
	Carmine	Desert	T. yustis	Pacific	Schoene	Strawberry	Tumid	Twospotted	Ludeni
Aldicarb[1]	0.3-1.0	0.6-1.0	0.6-1.0	--	--	0.6-1.0	--	0.3-1.0	--
Carbophenothion	0.25-0.75	0.375-0.5	--	--	0.25-0.5	0.375	--	0.25-0.75	--
Chlorpyrifos	1.0	0.25-1.0	--	--	--	0.25-1.0	1.0	0.25-1.0	--
Demeton	0.25	0.25-0.375	0.375	0.375	0.375	0.375	0.375	0.25-0.375	0.375
Dicofol	1.0-1.5	0.8-1.6	--	0.8-1.0	--	0.8-1.6	--	0.8-1.6	--
Dicrotophos	0.25-0.5	0.25-0.5	0.25-0.5	--	--	0.25-0.5	--	0.25-0.5	--
Disulfoton[2]	0.5-1.0	0.5-1.0	--	--	--	0.5-1.0	--	0.5-1.0	--
Ethion	0.25-1.5	0.25-0.75	0.25-1.0	--	0.25-1.0	0.25-0.1	--	0.25-2.0	--
Methamidophos	0.5-1.0	--	--	--	--	--	0.5-1.0	0.5-1.0	--
Methidathion	1.0	1.0	1.0	1.0	1.0	1.0	--	0.5-1.0	--
Methyl parathion	--	0.6	--	--	0.6	--	0.6	0.6	--
Monocrotophos	0.2-1.0	0.25-1.0	0.5-1.0	0.5-1.0	0.5-1.0	0.5-1.0	0.2-1.0	0.2-1.0	0.5-1.0
Oxydemeton-methyl	0.25-0.5	0.25-0.5	0.25-0.5	0.25-0.5	0.25-0.5	0.25-0.5	0.2-0.5	0.25-0.5	0.25-0.5
Parathion	--	0.25-0.5	0.1-0.2	--	--	--	0.25-0.5	0.125-1.0	0.2
Phorate[3]	0.5-1.5	0.5-1.5	--	--	--	0.4-1.5	--	0.5-1.5	--
Propargite	1.0-1.25	--	--	0.8-1.6	--	0.8-1.6	--	0.5-1.6	--
Sulfur	--	25-30	--	--	--	25-35	--	20-50	--

[1]In-furrow granule treatment at planting.
[2]In-furrow granule treatment at planting or 0.5 pound per hundredweight of planting seed.
[3]In-furrow granule treatment at planting or 1.3 to 1.5 pounds per hundredweight of planting seed.

Green stink bug, _Acrosternum hilare_ (Say)
Onespot stink bug, _E. variolarius_ (Palisot de Beauvois)
Redshouldered plant bug, _Thyanta custator_ (F.);
T. rugulosa (Say); _T. pallidovirens spinosa_ (Ruckers)
Say stink bug, _Chlorochroa sayi_ Stål
Southern green stink bug, _Nezara viridula_ (L.)
Western brown stink bug, _Euschistus impictiventris_ Stål

The importance of these pests and the species involved vary from year to year and from area to area. The damage is principally confined to the bolls and results in reduced yields and lower quality of both lint and seed. The following insecticides applied at the indicated dosages of technical material have given control of one or more species of stink bugs:

Spray	Pounds (AI) per acre
Carbaryl	2.0
Endosulfan	1.0
Methyl parathion	0.75-1.5
Parathion	0.5-1.0
Trichlorfon	1.0-1.5

Thrips

Thrips often injure cotton seedlings, especially in areas where vegetables, legumes, and small grains are grown extensively. The following species have been reported to cause injury:

Flower thrips, _Frankliniella tritici_ (Fitch);
F. exigua Hood; _F. gossypiana_ Hood; and _F. occidentalis_ (Pergande)
Onion thrips, _Thrips tabaci_ Lindeman
Soybean thrips, _Sericothrips variabilis_ (Beach)
Tobacco thrips, _F. fusca_ (Hinds)

In some areas cotton seedlings usually recover from thrips injury; therefore, control is not recommended unless the stand is threatened. In other areas damage by thrips is more severe and control measures are generally recommended. Injury from thrips alone, or the combined injury of thrips and disease, may reduce or even destroy stands of young plants. A heavy infestation may retard plant growth and delay fruiting and crop maturity. Although thrips are predominantly pests of seedlings, damaging infestations sometimes occur on older cotton in certain areas. The following insecticides at the indicated dosages of technical material are recommended when the situation warrants their use:

Spray	Pounds (AI) per acre
Acephate	0.1-0.2
Azinphosmethyl	0.08-0.2
Carbaryl	0.5-0.85
Chlorpyrifos	0.25-1.0
Dicrotophos	0.1-0.2
Dimethoate	0.1-0.25
Endosulfan	0.3-0.75
Malathion	0.25-1.3

Methamidophos	1.0
Methyl parathion	0.12-0.5
Monocrotophos	0.1-0.2 (0.6-1.0)[1/]
Parathion	0.5
Trichlorfon	0.25

[1/]The higher rate is used for controlling western flower thrips.

The following materials are effective when used as seed treatments or as in-furrow granule applications at planting at the indicated dosages of technical material:

Insecticide	Pounds per acre	Pounds (AI) per hundredweight of cottonseed
Acephate	---	0.4
Aldicarb	0.3-0.5	----
Disulfoton	0.6-1.0	0.25-0.5
Monocrotophos	---	0.25-1.25
Fenamiphos	1.6-3.3	0.25-1.25
Phorate	0.5-1.5	1.30-1.5

The bean thrips, *Caliothrips fasciatus* (Pergande), is an occasional mid- to late-season pest of cotton in parts of California. *Caliothrips phaseoli* (Hood) damaged cotton near Bard, Imperial County, CA, in 1962. *Scirtothrips* spp. causes severe crinkling of the top leaves of cotton in localized areas of Arizona, Mississippi, and Texas. *Kurtomathrips morrilli* Moulton was described in 1927 from specimens taken on cotton at Gila Bend, AZ. It was collected from cotton at Seeley, CA, in May, 1930, and at Laveen, AZ, in July, 1943, and was reported to have caused severe injury to cotton at Gila Bend in July, 1957. *Frankliniella gossypiana* rarely occurs on cotton in the eastern United States; *F. occidentalis* has been reported damaging cotton in Georgia in 1980-83. In the West, *F. tritici* is of little importance on cotton, and *F. fusca* does not occur.

Whiteflies

The bandedwing whitefly, *Trialeurodes abutilonea* (Haldeman), the greenhouse whitefly, *T. vaporariorum* (Westwood), and the sweetpotato whitefly, *Bemisia tabaci* (Gennadius), are usually kept in check by parasites and diseases, but occasionally may be serious pests late in the season. The bandedwing whitefly has been a problem in Louisiana since 1964, and infestations have increased in Mississippi, Alabama, Arkansas, Oklahoma, and Georgia since 1972. The bandedwing whitefly may be controlled with monocrotophos (0.25-1.0), with methamidophos (0.25-0.5), with acephate (0.5-1.0), and with methidathion (0.25 to 0.5 pound per acre).

Whitefringed Beetles, *Graphognathus* spp.

Whitefringed beetles are pests of cotton and many other farm crops in limited areas of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee. Infestations in recent years have been discovered in Maryland, Virginia, and Texas. The larvae feed on the roots of young plants.

Wireworms

Several species of wireworms are associated with cotton. Damage is caused by the sand wireworm, *Horistonotus uhlerii* Horn, in South Carolina and Louisiana, by *Melanotus* spp. in Louisiana and Mississippi, and by the Pacific Coast wireworm, *Limonius canus* LeConte, in California. Adults of the tobacco wireworm (or spotted click beetle), *Conoderus vespertinus* (F.), are frequently found on the cotton plant, and the larvae caused damage to cotton in Louisiana in 1981. Wireworms, together with false wireworms and the seedcorn maggot, sometimes prevent the establishment of a stand. Approved crop-rotation practices, increased soil fertility, and added humus help to reduce damage to cotton by the sand wireworm. Chlorpyrifos at a rate of 2 pounds (AI) per acre has SLN approval for use only in Mississippi.

Yellowstriped Armyworm, *Spodoptera ornithogalli* (Guenée), and Western Yellowstriped Armyworm, *S. praefica* (Grote)

These insects sometimes cause considerable damage to cotton. The yellowstriped armyworm is difficult to kill with insecticides. However, chlorpyrifos (0.25-1.0), trichlorfon (1.5) monocrotophos (0.5 - 0.75) and methyl parathion (1 to 1.5 pounds per acre) give good control of large and small larvae. The western yellowstriped armyworm, which attacks cotton in California and Texas, is controlled with trichlorfon at 0.75-1.0 pound per acre. Migrations from surrounding crops may be stopped with barriers of 5 percent trichlorfon or 5 percent carbaryl at 2 pounds per 100 linear feet.

Miscellaneous Insects

The brown cotton leafworm, *Acontia dacia* Druce, has been reported as a pest of cotton in Arkansas, Louisiana, and Texas. This pest may be controlled with azinphosmethyl (0.25), malathion (0.25), and parathion (0.125 pound per acre).

Several *Anomis* leafworms occur in the cotton-growing regions of Africa; Asia; Australia; North, Central, and South America; and the East and West Indies. Three species--*A. erosa* Hübner, *A. flava fimbriago* (Stephens), and *A. texana* Riley--occasionally damage cotton in the United States. They are often mistaken for the cotton leafworm and are sometimes found on the same plants with it. Although specific control data are lacking, the insecticides recommended for control of the cotton leafworm might also be effective against *Anomis* leafworms.

Root aphids known to attack cotton are the corn root aphid, *Aphis maidiracidis* Forbes; *Smynthurodes betae* (Westwood); and *Rhopalosiphum rufiabdominalis* (Sasaki). So far as is known, injury before 1956 was confined to the eastern seaboard. More recently, root aphids have caused some damage to cotton in Arkansas, Missouri, New Mexico, and North Carolina. Several species of ants are known to be associated with root aphids, the principal one being the cornfield ant, *Lasius alienus* (Foerster). Chemical control of root aphids has been directed at this ant. Root aphids injure cotton chiefly in the seedling stage. Since cotton in this stage shows injury without any evidence of insects being present, the underground parts should be examined carefully. Ant mounds at the base of these plants indicate the presence of root aphids.

The cowpea aphid, *Aphis craccivora* Koch, the green peach aphid, *Myzus persicae* (Sulzer), and the potato aphid, *Macrosiphum euphorbiae* (Thomas), are common on seedling cotton. Cotton is not believed to be a true host of these species.

The garden springtail, *Bourletiella hortensis* (Fitch), has been observed on cotton in North Carolina, and another springtail, *Entomobrya unostrigata* Stach, has occasionally damaged seedling cotton over a wide area of the southern High Plains of Texas and New Mexico.

The corn silk beetle, *Calomicrus brunneus* (Crotch), has been a pest of cotton in localized areas of South Carolina, Georgia, Alabama, Mississippi, and Louisiana, but little is known about it.

Leaf beetles of the genus *Colaspis* are widespread and often found on cotton, frequently on the foliage or near the base of squares and bolls where they usually feed on the surrounding bracts.

The cowpea curculio, *Chalcodermus aeneus* Boheman, sometimes causes damage to seedling cotton, and other curculionids; *Compsus auricephalus* (Say), (Arkansas, Oklahoma, Tennessee, and Texas), *Conotrachelus erinaceus* LeConte, (Alabama), and *Otiorhynchus cribricollis* Gyllenhal, (New Mexico); have been reported as pests of cotton seedlings and young plants.

The spotted cucumber beetle, *Diabrotica undecimpunctata howardi* Barber, has been reported as an occasional pest of cotton in Tennessee. Adults may feed in the ovary of the bloom, resulting in loss of the young boll, or on squares.

The cotton stainer, *Dysdercus sututellus* (Herrich-Schaffer), is found within the United States in Florida only. However, probably owing to mistaken identity, its presence has also been recorded in Alabama, Georgia, and South Carolina.

Several leafhoppers of the genus *Empoasca* are often abundant on cotton in many sections of the Cotton Belt. Serious injury has been reported only in California, however, and this was caused by two species, the southern garden leafhopper, *E. solana* DeLong, and the potato leafhopper, *E. fabae* (Harris). These species are known to be phloem feeders on some crops and cause damage typical of this type of feeding on cotton. Sprays of trichlorfon (1.0), malathion (1.0), parathion (0.5), or demeton (0.25 pound per acre) have given satisfactory control.

The striped blister beetle, *Epicauta vittata* (F.), sometimes causes severe foliage damage in small localized areas. Damage usually results when weeds, which are preferred host plants, are cleaned out of cotton. Total loss of foliage may result in small areas before the insects move out of the field.

Field crickets, *Gryllus* spp., have been reported feeding on cotton bolls and young plants in California, Arizona, and Arkansas. During periods of drought late in the season, they also may feed on the seed of open bolls, especially in the Delta sections of Arkansas, Louisiana, and Mississippi. This feeding is usually done at night, since crickets hide during the day in deep cracks in the soil.

The whitelined sphinx, *Hyles lineata* (F.), occasionally occurs in large numbers in uncultivated areas and migrates to cotton. In 1983, this insect was observed feeding on cotton foliage in localized areas in Mississippi. It may be controlled on cotton with sprays of carbaryl (1.5-2.0), or trichlorfon (0.5-1.0 pound per acre).

Serpentine leafminers (*Liriomyza* spp.) including *L. pictella* (Thomson), have been present in large numbers in some areas of California during the last few years. Drought conditions favor infestations of these pests. Heavy infestations may result in considerable shredding of leaves. Infestations are brought under control by rain or irrigation. Field tests at Waco, TX, showed that the best reductions were obtained with parathion at 1.0 pound per acre. Seed treatment of phorate at 0.25-0.5 and disulfoton at 1.0 pound per acre are also effective 4 to 6 weeks after planting.

Damage to cotton by periodical cicadas, Magicicada spp., in the United States was first reported in 1905. Damage is caused by the deposition of eggs in the stems of young plants, branches of older plants, and occasionally in leaf petioles. The parts of the plant above the oviposition puncture usually die, and growth below the puncture results in low, bushy plants. Severe local damage to cotton by Diceroprocta vitripennis (Say) has been reported in Arkansas.

The barberpole caterpillar, Mimoschinia rufofascialis (Stephens), a pyralid larva, occasionally attacks cotton bolls in the Imperial and San Joaquin Valleys of California. It also has been reported from Arizona, Oklahoma, and Texas.

Bugs of the genus Nysius, N. ericae (Schilling), Xyonysius californicus Stål, and N. raphoanus Howard, commonly called false chinch bugs, frequently migrate to cotton from adjacent weed hosts. Stands of seedling cotton may be destroyed by adults and nymphs. Methyl parathion and parathion are effective at 0.5 pound per acre.

The European corn borer, Ostrinia nubilalis (Hübner), was first reported on cotton in the United States during 1955. The first report came from Franklin County, TN, where a few plants near the edge of a field were severely damaged. Subsequently, light infestations have been reported in cotton in Alabama, Florida, Louisiana, Mississippi, South Carolina, and Tennessee. The larvae are usually found boring into the upper third of the stems, and second- and third-instar larvae may attack small bolls. In other parts of the world, particularly in Russia, Turkistan, and Hungary, it has been a serious pest of cotton. One reference states, "In Turkistan it is principally cotton which is attacked by the larvae and in which they bore long tunnels in the upper part of the stem." Entomologists and other interested persons throughout the Cotton Belt should be on the alert to detect its presence and, whenever possible, record the type and degree of injury, seasonal and geographical distribution, and control measures that might be of value.

The Fuller rose beetle, Pantomorus cervinus (Boheman), is occasionally a pest of cotton. It is a leaf feeder and usually attacks cotton in the early season, causing ragging of the leaves and partial defoliation. It overwinters as an adult in about the same habitat as the boll weevil. Examinations of woods surface trash for hibernating boll weevils often reveal specimens of the Fuller rose beetle. Its presence in cotton has been reported from Georgia more frequently than from any other area.

The stalk borer, Papaipema nebris (Guenee), is widely distributed east of the Rocky Mountains. It attacks many kinds of plants, including cotton, and can be highly destructive. The borer is most likely to be seen near the edges of cotton fields. It has caused some injury to cotton in Mississippi, Missouri, and Tennessee. This pest is sometimes mistaken for the European corn borer. Clean cultivation and the keeping down of weed growth help to hold it in check. The use of stalk shredders early in the fall should reduce its numbers.

The white grub, Phyllophaga ephilida (Say), has caused localized damage of cotton in North Carolina, and P. zavalana Reinhard has been reported as a pest of cotton in Mexico and Texas. Phyllophaga cribros (LeConte), sometimes known as the "4 o'clock bug" in west Texas, has also been observed feeding on young cotton in that area. Moderate damage of young cotton plants by larvae of P. implicita (Horn) has been reported in the Arkansas Delta area.

The cotton stem moth, Platyedra subcinerea (Haworth), a close relative of the pink bollworm, was first discovered in the United States in 1951, when larvae were found feeding in hollyhock seed in Meneola, Long Island, NY. It is a pest of cotton in Iran, Iraq, Morocco, Turkistan, and the U.S.S.R. and feeds on hollyhock and other malvaceous plants in England, France, and central and southern Europe. Subsequently collections in this country have indicated its

presence in Connecticut, New Hampshire, New Jersey, New York, and Massachusetts. Although this species has not been found in the Cotton Belt in the United States, it is desirable to keep on the lookout for it on cotton, hollyhock, and other malvaceous plants. In 1956 it was collected from a natural infestation on cotton growing on the laboratory grounds at Farmingdale, New York.

Heavy feeding on cotton by the Japanese beetle, Popillia japonica Newman, has been reported occasionally in some areas of North Carolina.

Several of the leaf rollers, Tortricidae, occasionally damage cotton. Platynota stultana (Walsingham) and P. rostrana (Walker) are the species most commonly recorded, but P. flavedana (Clemens) and P. idaeusalis (Walsingham) have also been reported. These species are widely distributed and have many host plants. Playnota stultana has at times been a serious pest of cotton in the Imperial Valley of California and parts of Arizona and New Mexico. Trichlorfon at 1.0 or carbaryl at 2.0 pounds per acre have satisfactorily controlled the species that occur on cotton in California.

Adults of the buprestid beetle, Psiloptera drummondi (Laporte and Gory), occasionally cause damage to cotton. The damage consists of partly girdled terminals that break over and die.

The pink scavenger caterpillar, Sathrobrota rileyi (Walsingham), is one of several insects that resemble the pink bollworm and is sometimes mistaken for it by laymen. The larva is primarily a scavenger in cotton bolls and cornhusks that have been injured by other causes.

The cotton square borer, Strymon melinus (Hübner), occurs throughout the Cotton Belt but rarely causes economic damage. The injury it causes to squares is often attributed to the bollworm.

The palestriped flea beetle, Systena blanda Melsheimer, the elongate flea beetle, S. elongata (F.), and S. frontalis (F.) sometimes cause serious damage to seedling cotton in some areas. The sweetpotato flea beetle, Chaetocnema confinis Crotch, has caused injury to seedling cotton in the Piedmont section of South Carolina and the striped flea beetle, Phyllotreta striolata (F.), has damaged cotton in Alabama.

The greenhouse leaftier, Udea rubigalis (Guenée), also known as the celery leaftier, has occasionally been abundant on cotton in the San Joaquin Valley. Despite the heavy populations, damage was generally slight and restricted to foliage on the lower third of the plants in lush stands. In the few places where it was necessary to control this pest, endrin at 0.4 pound per acre in a dust or spray was effective. This pest has also been reported as a pest of cotton in Arizona. The false celery leaftier, Udea profundalis (Packard), has caused considerable defoliation of cotton in some fields in California. Control was difficult because of the insect's feeding habits on the lower part of plants within a web. Carbaryl at 2.0 or trichlorfon at 1.0 pounds per acre were effective against this pest.

Damage to cotton stalks by undetermined species of termites has been reported in Tennessee and in Texas. Termites, Reticulitermes sp. (family Rhinotermitidae), partly destroyed a stand of cotton in Little River County, Arkansas.

During 1982 reports from Louisiana indicated large numbers of soybean looper, Pseudoplusia includens (Walker), moths in most cotton and serious defoliation by the looper larvae in some irrigated cotton. Georgia reported foliage feeding with minor to complete defoliation in some fields in both 1981 and 1982.

Some other species occasionally observed feeding on cotton include the harlequin bug, Murgantia histronica (Hahn) (Arizona); a giant appletree borer, Prionus spp. (Arkansas); the roughskinned cutworm, Proxenus mindara Barnes and McDunnough (California); and tree crickets, Oecanthus spp. (Oklahoma).

Insects in Stored Cottonseed and Seed Cotton

Insect infestations in cottonseed during storage can be minimized if proper precautions are followed. Cottonseed and seed cotton should be stored only in a bin or room thoroughly cleaned of all old cottonseed, grain, hay, or other similar products in which insects that attack stored products are likely to develop. Among the insects that cause damage to stored cottonseed or to cottonseed meal are the cigarette beetle, *Lasioderma serricorne* (F.), the Mediterranean flour moth, *Anagasta kuehniella* (Zeller), the almond moth, *Cadra cautella* (Walker), and the Indian meal moth, *Plodia interpunctella* (Hübner). Other insects commonly found in cottonseed are the flat grain beetle, *Cryptolestes pusillus* (Schönherr), the red flour beetle, *Tribolium castaneum* (Herbst), and the sawtoothed grain beetle, *Oryzaephilus surinamensis* (L.). Malathion is registered as a seed treatment for cottonseed. Seed so treated should not be used for food or feed. The pink bollworm, *Pectinophora gossypiella* (Saunders), may be found in stored cottonseed, but such infestations would be present in the seed before they are stored.

INSECT IDENTIFICATION AND COTTON-INSECT SURVEYS

Prompt and accurate identification of insects and mites is a necessary service to research and for the control of cotton insects. Approved common names are convenient and useful, but local or nonstandard common names create confusion. Entomologists are urged to submit common names to the ESA Committee on Common Names of Insects for consideration, where such are needed as for *Lygus hesperus*. Research in taxonomy has been productive of new developments. Major changes have been made in the classification of spider mites that attack cotton. Several species of thrips and plant bugs have recently been added to the list of cotton pests. The *Melanoplus mexicanus* group of grasshoppers has been completely revised, *Heliothis virescens* (F.) has been accurately defined, and several scientific names have been changed.

The importance of surveys to an overall cotton-insect control program has been clearly demonstrated. Surveys conducted on a cooperative basis by State and Federal agencies in most of the major cotton growing States have developed into a broad, up-to-date advisory service for the guidance of county agents, ginners, farmers, and other leaders in agriculture who are interested in the distribution and severity of cotton-insect pests, as well as the industry that serves the farmers by supplying insecticides. As a result of this survey work, farmers are forewarned of the insect situation, insecticide applications are better timed, and losses are materially reduced below what they would be without the information thus gained. The surveys also help to direct insecticides to areas where supplies are critically needed.

It is recommended that cotton-insect surveys be continued on a permanent basis, that they be expanded to include all cotton producing States, and that the survey methods be standardized. It is further recommended that the greatest possible use be made of fall, winter, and early spring surveys as an index to the potential infestation of next season's crop. Each year more people are being employed by business firms, farm operators, and others to determine cotton-insect populations. State and Federal entomologists should assist in locating and training personnel that have at least some basic knowledge of entomology. Whenever possible, voluntary cooperators should be enlisted and trained to make field observations and records and to submit reports during the active season.

Surveys to detect major insect pests in areas where they have not previously been reported may provide information that can be used in restricting their spread or in planning effective control programs. The survey methods may include (1) visual inspection, (2) using traps containing aromatic lures or sex and aggregating pheromones, (3) using light traps, (4) using mechanical devices such as gin-trash machines, (5) examination of glass windows installed in lint cleaners used in ginning, and (6) using portable vacuum devices for sampling insect populations. The methods of making uniform surveys on several of the important insects are described below. Light traps have provided valuable survey information on the beet armyworm, bollworm, brown cotton leafworm, cabbage looper, cotton leafworm, cutworms, fall armyworm, garden webworm, pink bollworm, saltmarsh caterpillar, whitelined sphinx, yellowstriped armyworm, and yellow woollybear. Pheromone traps have provided valuable survey information on the boll weevil, bollworm, pink bollworm, tobacco budworm, cabbage looper, and fall armyworm.

Boll Weevil

Surveys to determine winter survival of the boll weevil are made in several States. Counts are made in the fall soon after the weevils have entered hibernation and again in the spring before they emerge from winter quarters. A standard sample is 2 square yards of woods surface trash taken from the edge of a field where cotton was grown in the previous season. Three samples are taken from each of 30 locations in an area, usually consisting of 3 or 4 counties. Fall and spring catches of weevils in pheromone traps are used to supplement or replace counts from surface wood trash.

In the main boll weevil area, counts are made on seedling cotton to determine the number of weevils entering cotton fields from hibernation quarters. The number per acre is figured by examining the plants on 50 feet of row in each of 5 representative locations in the field and multiplying the total by 50. Additional counts are desirable in large fields.

Square examinations are made weekly after the plants are squaring freely or have produced as many as three squares per plant. While walking diagonally across the field, pick 100 squares, one-third grown or larger, taking an equal number from the top, middle, and lower branches. Do not pick squares from the ground or flared or dried-up squares that are hanging on the plant. The number of squares found to be punctured is the percentage of infestation. To obtain a total of 100 to 500 squares, an alternate method is to inspect about 25 squares in each of several locations distributed over the field. The number of squares inspected depends upon the size of the field and the surrounding environment. The percentage of infestation is determined by counting the punctured squares. In both methods all squares that have egg or feeding punctures should be counted as punctured squares. Sequential sampling, also based on square inspections, requires fewer squares to be inspected in making pest management decisions at about a 90-percent level of reliability.

The point-sample method developed by Arkansas entomologists consists of the following procedures: Select a representative area in a field and mark a starting point on a row. Examine the first 50 green squares that are one-fourth inch or larger in diameter for boll weevil punctures. Count those that are punctured and step off the feet of row required for the 50 squares. Four such counts, a total of 200 squares, are adequate for uniform fields up to 40 acres in size. Fields that are larger or that are not uniform should be considered as separate fields with four counts made in each. The percentage of punctured

squares, number of squares per acre, and number of punctured squares per acre can be determined from the point-sample information.

A conversion table for usual row widths in an area with various numbers of row feet, 1 to 250, required for a 200-square count is prepared for ease in determining the number of squares and punctured squares per acre. Example: If 10 feet of a 40-inch row are required for 200 squares, there are 261,000 squares per acre. If 50 percent of the squares are punctured, there are 130,500 punctured squares per acre.

Bollworm and Tobacco Budworm

Examinations for bollworm eggs and larvae should be started as soon as the cotton begins to square and repeated every 5 days, if possible, until the crop has matured. In some areas it may be necessary to make examinations for bollworm damage before cotton begins to square. While walking diagonally across the field examine the top 3 or 4 inches of the mainstem terminals, including the small squares, of 100 plants. Whole-plant examinations should be made to insure detection of activity not evident from terminal counts. Sequential sampling, also based on terminal, square, and boll inspections, requires fewer inspections of terminals, squares, and bolls in making pest management decisions at about a 90-percent level of reliability. Eggs of cutworms, cabbage loopers, and other lepidopterous species are sometimes mistaken for those of the bollworm. The percentage of damaged squares, number of squares per acre, and number of damaged squares can be determined by using the point-sample method given under "Boll Weevil" above.

Cotton Aphid

To determine early-season cotton aphid infestation, walk diagonally across the field and examine many plants; then record the degree of infestation as follows:

None, if none is observed.
Light, if aphids are found on an occasional plant.
Medium, if aphids are present on numerous plants and some of the leaves curl along the edges.
Heavy, if aphids are numerous on most of the plants and the leaves show considerable crinkling and curling.

To determine infestations on fruiting cotton, begin at the margin of the field and, while walking diagonally across it, examine 100 leaves successively from near the bottom, middle, and top of each plant. Record the degree of infestation, according to the average number of aphids estimated per leaf as follows:

None, 0.
Light, 1 to 10.
Medium, 11 to 24.
Heavy, 26 or more.

Cotton Fleahopper

Weekly inspections should begin as soon as the cotton is old enough to produce squares. In some areas inspections should be continued until the crop is

set. While walking diagonally across the field, examine 3 or 4 inches at the top of the mainstem terminals of 100 cotton plants--counting both adults and nymphs. Sequential sampling, also based on terminal inspections, requires fewer than 100 terminal inspections in making pest management decisions of about a 90-percent level of reliability. To determine populations, white or black cloth sheets are placed under the plants, which are then thoroughly shaken. Ten 3-row-foot samples are taken at random within a field. Populations are recorded on a per-acre basis.

Cotton Leafworm

The following levels of leafworm infestation, on the basis of ragging of leaves and the number of larvae per plant, are suggested for determining damage:

None, if none is observed.
Light, if 1 or only a few larvae are observed.
Medium, if 2 to 3 leaves are partly destroyed by ragging, with 2 to 5 larvae per plant.
Heavy, if ragging of leaves is extensive, with 6 or more larvae per plant, or if defoliation is complete.

Lygus Bugs and Other Mirids

Inspections should be made at 3- to 7-day intervals, beginning at pinhead square stage and continuing until early September. Infestations should be determined by making a 50- to 100-sweep count at each of four or more locations. Sweeping is accomplished by passing a 15-inch net through the tops of the plants in one row, with the lower edge of the net slightly preceding the upper edge. Contents of the net should be examined carefully to avoid overlooking very small nymphs. The plant terminal inspection, as described for the cotton fleahopper, may also be used. During hot summer weather, sweeping should not be made between 11:30 a.m. and 3:00 p.m., since lygus bugs are prone to move into plant cover to avoid heat. Population determinations are made using the cloth-sheet method described above for cotton fleahoppers. Sequential sampling, also based on terminal inspections or sweep-net counts, requires fewer terminal inspections or net sweeps in making pest management decisions at about a 90-per-cent level of reliability.

Pink Bollworm

Counts to determine the degree of infestation in individual fields may be made early in the season by inspecting blooms and later by inspecting bolls. Bloom inspections for comparing yearly early-season populations should be made to obtain an estimate of the number of larvae per acre.

<u>Bloom inspection.</u>--Five days after the first bloom appears, but not later than 15 days, check for number of larvae per acre as follows: Step off 300 feet of row (100 steps), and count the rosetted blooms at five representative locations in the field (1,500 feet). Add the number of rosetted blooms from these five locations, and multiply by 10 to obtain the number of larvae per acre.

<u>Boll inspection.</u>--Check weekly for the percentage of bolls infested as follows: Walk diagonally across the field and collect at random 100 bolls (2/3 grown or larger). Crack each boll and examine the inside of the hull for tunnels made by young larvae. Where tunneling is not found, check lint and seed

for evidence of larval feeding. Record the number of bolls infested on a percentage basis.

Other inspection techniques.--Other inspection methods, discussed below, are helpful in directing control activities against the pink bollworm. They make possible the detection of infestations in previously uninfested areas and the evaluation of increases or decreases as they occur in infested areas. They are also used to determine the population of larvae in hibernation and their carryover to infest the new cotton crop.

1. Inspection of lint cleaner: During the ginning process the free larvae remaining in the lint are separated in the lint cleaners, and a substantial number of them are thrown and stuck on the glass inspection plates; all these larvae are dead. For constant examination at a single gin, wipe off the plates and examine after each bale is ginned. In this way the individual field that is infested may be determined. For general survey, make periodic examinations to detect the presence of the pink bollworm in a general area.

2. Examination of debris: Between January and the time squares begin to form in the new crop, examine old bolls or parts of bolls from the soil surface in known infested fields. Examine the cotton debris from 50 feet of row at five representative points in the field for the number of living pink bollworms. Multiply by 50 to determine the number of living larvae per acre. Such records, when maintained from year to year, provide comparative data that may be used in determining appropriate control measures.

3. Use of sex lure traps: Traps containing formulations of the synthetic sex pheromone (gossyplure) are used in detection of male pink bollworms. Gossyplure-baited traps are efficient in detecting the pink bollworm and can provide information which facilitates the timing of insecticide applications in some areas.

Spider Mites

Examine 25 or more leaves from representative areas within a field taken successively from near the bottom, middle, and top of each plant. Record, according to the average number of mites per leaf, the degree of infestation as follows:

None, 0.
Light, 1 to 10.
Medium, 11 to 25.
Heavy, 26 or more.

Thrips

While walking diagonally across the field, examine the plants and record the damage as follows:

None, if no thrips or damage are found.
Light, if newest unfolding leaves show only a slight brownish tinge along the edges, with no silvering of the underside of these or older leaves, and only an occasional thrips is seen.
Medium, if newest leaves show considerable browning along the edges and some silvering on the underside of most leaves, and thrips are found readily.
Heavy, if silvering of leaves is readily noticeable, terminal buds show injury, general appearance of plants is ragged and deformed, and thrips are numerous.

Plants beaten over a thrips box or over a piece of cloth may be used to determine the numbers of thrips per plant. Use of sequential sampling will usually reduce the number of plants needed to determine population levels with no loss in accuracy.

Predators

Populations of predators may be estimated by counting those seen while examining leaves, terminals, and squares for pest insects. When special counts for predators only are made, examination of whole plants is more efficient in estimating populations. Population determinations are made using the cloth-sheet method described for the cotton fleahopper. Use of sequential sampling will usually reduce the number of sample units needed in making pest-management decisions at about a 90-percent level of reliability.

Cotton Pests Outside of the Continental United States

Some major pests of cotton in other countries and Hawaii that do not occur in the continental United States and that might be accidentally introduced into this country at any time are listed in table 6. Cotton farmers, cotton scouts, county agents, entomologists, and others should be alerted to the possibility of these pests becoming introduced into this country and should collect and submit for identification any insect found causing damage to cotton if its identity is in doubt.

Table 6.--Some major cotton pests in other countries and Hawaii

Family and species	Common name	Plant parts damaged	Distribution
Cicadellidae:			
Empoasca lybica (Bergevin)	Cotton jassid	Foliage	Africa, Spain, Israel
Curculionidae:			
Amorphoidae lata Motschulsky	Philippine cotton boll weevil	Squares, bolls	Philippine Islands
Anthonomus vestitus Boheman	Peruvian cotton square weevil	Similar to that of A. grandis	Peru, Ecuador
Eutinobothrus brasiliensis (Hambleton)	Brazilian cotton borer	Stems, roots	Brazil, Argentina
Pempherulus affinis (Faust)	Cotton stem weevil	Stems	Southeastern Europe, Philippine Islands
Gelechiidae:			
Pectinophora scutigera Holdaway	Pinkspotted bollworm	Bolls	Australia
Pexicopla malvella (Hübner)		Bolls	Pakistan
Lygaeidae:			
Oxycarenus Costa	Cottonseed bug	Seed, lint	Africa, Asia, Phillipine Islands
Miridae:			
Horcias nobilellus (Berg)	Cotton plant bug	Terminals, squares, young bolls	Brazil, Argentina, Paraguay
Lygus luccrum Meyer-Dür	Do	Do	China
Taylorilygus vosseleri Poppises	Do	Do	Africa
Noctuidae:			
Diparopsis castanea Hampson	Red bollworm	Bolls	Africa
Earias insulana (Boisduval)	Spiny bollworm	Young growth, bolls	Africa, Asia
Earias vittella (F.)	Spotted bollworm	Terminals, squares, bolls	India, Pakistan, Thailand
Heliothis armigera (Hübner)	Cotton bollworm	Terminals, squares, bolls	Australia, Africa, Asia, Southern Europe, People's Republic of China

Table 6.--Some major cotton pests in other countries and Hawaii--Continued

Family and species	Common name	Plant parts damaged	Distribution
Heliothis punctigera (Wallings)	Budworm	Terminals, squares, bolls	Australia
Sacadodes pyralis Dyar	False pink bollworm	Squares, bolls	Central and South America
Spodoptera littoralis (Boisduval)	Egyptian cotton leafworm	Foliage, squares	Africa
Spodoptera litura (F.)	Old World cotton leafworm	Foliage, squares	Asia, Southern Europe, Hawaii, Pacific Islands
Olethreutidae:			
Cryptophlebia leucotreta (Meyrick)	False codling moth	Bolls	Africa
Pseudococcidae:			
Maconellicoccus hirsutus Green	Hibiscus mealybug	Foliage terminals	Asia, Africa
Pyralidae:			
Sylepta derogata (F.)	Cotton leaf roller	Foliage	Africa, Asia, Australia, Pacific Islands
Pyrrhocoridae:			
Dysdercus peruvianus Guerin	Peruvian cotton stainer	Bolls	Brazil, Colombia, Peru, Venezuela

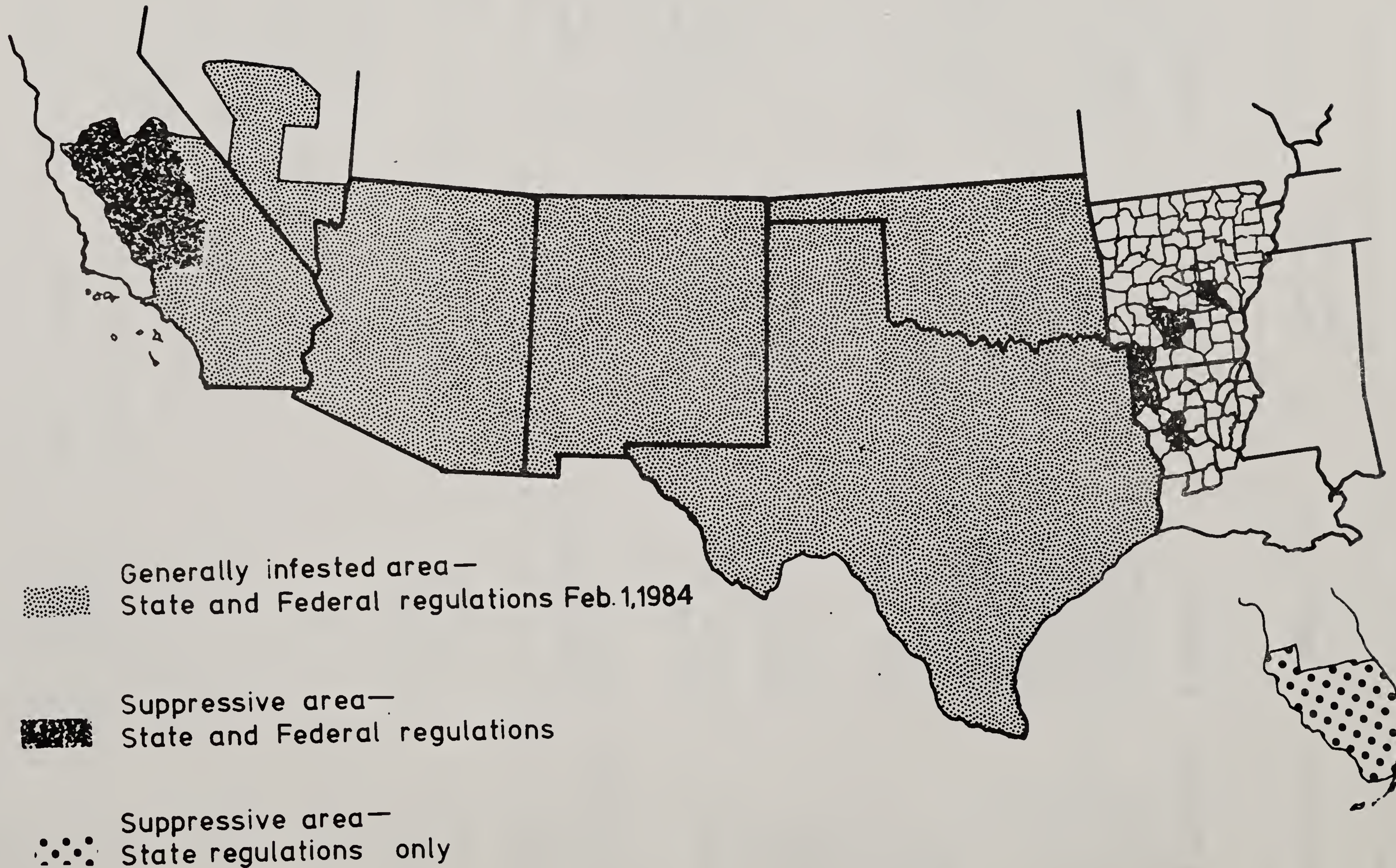

Figure 1.--Areas of the United States where the pink bollworm is presently under Federal and State regulations.

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